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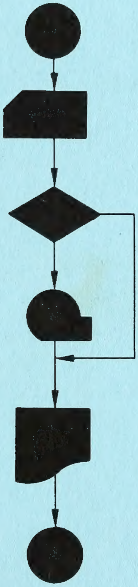
THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM

I. INTRODUCTION



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Robert W. Wilson Jr.
and Robert C. Peters

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

About the Authors . . .

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ROBERT C. PETERS obtained his Bachelor's degree from the University of California in 1960 and his Master's at Yale University in 1961. He joined the Forest Service in 1961 as a research forester, and was assigned to the Station's biometrics unit from 1961 until 1965, when the unit was discontinued. Mr. Peters played a key role in the development of the data-processing system reported here.

THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM

I. INTRODUCTION

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PREFACE

THIS paper in the first in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers—subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers—subsystem OUTPUT.

I-A. Introduction

ONE of the major projects of the U. S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

The purpose of this paper—and the nine companion papers that will follow—is to describe the system and its operation for the benefit of others who have similar problems in data processing.

Groundwork for the system was laid in 1960, when biometrician C. Allen Bickford[1] of the Northeastern Forest Experiment Station and biometrician W. G. O'Regan of the Pacific Southwest Forest and Range Experiment Station pointed out the possibilities and proposed the development of a standard computer program for the forest survey.

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[1] Mr. Bickford, who retired from the U. S. Forest Service in 1963, is now on the faculty of the New York State University College of Forestry at Syracuse.

The authors of this paper were assigned to this project, and along with Bickford began to develop this program in the summer of 1961. The principal goals of the program were: (1) that the standard tables required of the forest survey were to be calculated and printed in a format suitable for publication; and (2) that each entry in every table would have a calculated sampling error.

In 1962, when this first program was developed, it was used for processing the inventory data collected in the forest survey of West Virginia. By this time several new inventories were under way, and some were completed except for data processing.

At this point it was evident that the standard computer program was already outdated because each new survey was different in at least one minor respect from the West Virginia survey; and although apparently minor, a difference often required a major alteration of the program. For this reason, the standard-program concept had to be changed to a more flexible one.

The present system is an outgrowth of several attempts to develop and to use both special-purpose and partially generalized systems to process the northeastern forest-survey inventory data. The features that give the system its flexibility are absolutely essential to an effective and economical data-processing operation. Differences between data-processing jobs appear to be inevitable. Even though all our processing jobs originate within a single organization operating under a stable set of general policies and objectives, differences of three principal kinds arise: (1) differences in required and optional resource statistics (output tables); (2) differences in measurement techniques, input data, and associated calculations; and (3) differences in sampling designs.

Differences of output tables arise primarily as reflections of differences of objectives among important users of resource statistics. In general, differences of this kind are small, but they are also unpredictable and difficult to adjust because they affect every step of the processing from input to output. Therefore provision must be made to accommodate these differences automatically from detailed descriptions of the output tables required for each processing job. Otherwise adjustments will be slow and expensive to make.

Differences in measurement techniques have many sources. Among the important ones are: technological improvements in measurement techniques, the value of data obtained with older techniques, and differences in the kind of resource being measured. Although organizational policy may properly demand standards of measurement, it would be both undesirable and unrealistic to expect that all differences can be eliminated. In fact, considering the number of reasonable alternatives to the measurement of each of the attributes of a resource, one must expect a large number of differences. The nature of these differences is largely unpredictable except in general terms. Virtually the only way that these differences can be accommodated is by providing for the input of detailed descriptions of measurement checks and calculations with the data for each processing job.

Although differences in sampling designs may be large in effect, the number of different designs in common use is few; and the associated differences in compilation procedures are relatively small. Consequently it has been possible to incorporate in the system fully detailed procedures for each of the more common alternatives. Only the appropriate alternative need be indicated in the specifications for each processing job.

The system as finally developed encompasses all the processing of inventory data from field recording sheets to the printing of labeled tables of resource statistics. The system features variable inputs, variable outputs, and variable processing procedures for getting from one to the other. The user needs only to specify his particular processing problem in terms of the procedural options offered in the system. Consequently, the system is a general one, applicable to a wide variety of inventory-processing problems. Yet, for the user who has adopted standard procedures that he uses repeatedly, the system retains the advantage of a special-purpose system. Once he has exercised his options, he can incorporate them into his system, and they remain a part of it until such time as he wishes to change it. Changes are accomplished simply by making appropriate changes in the choice of options; there is no need to develop a completely new system or to undertake the hazardous task of patching the original system.

In short, the system provides all the information channels and detailed procedures necessary for processing inventory data while giving the user freedom to choose how his data should be handled for best results.

Other features of the system are its organization, designed to require the minimum of manual data handling consistent with the desired flexibility; and its use of large modern high-speed computers. The result is a capacity for consistent, rapid, low-cost processing of large volumes of inventory data.

I-B. System Outputs

The primary output from the system consists of a set of up to 40 one- or two-dimensional tables, designed to contain the required resource statistics for each survey unit or group of survey units for which inventory data inputs are given. Similar outputs may be obtained for subdivisions of survey units. If more than 40 output tables are required, the data must be passed through at least part of the system a second time; otherwise only one pass of the data is required.

Each table contains a particular summary of one or more sampling-unit attributes over the entire population of sampling units. The basic statistic may be either the sums or the means of the sampling-unit attributes. If the inventory data input is a sample from the population, additional tables of the same format are output automatically; they contain the variance of the statistic, and optionally, its standard error. Row, column, and grand totals are also provided automatically for each table. The tables are printed complete with appropriate labels provided by the user.

In addition to the primary output, almost any other type of output can be obtained, given adequate specifications by the user. The intermediate outputs from the main processing stages can be obtained simply by specifying that they be saved. Special outputs representing each unit record and/or any sets of unit records can be obtained from one stage of processing, EDIT. Special outputs representing each sampling unit can be obtained from another processing stage, TABLE.

I-C. Inventory Data Inputs

Inventory data are nothing more than a catalog or itemized list of objects, or categories of objects, that have actually been observed. It is in the form of such a list that data are used in processing, but the inputs need not be presented to the system in this form. The only limitations on the data inputs are that each item in such a list is expressible as a unit record that contains complete identification and description (values for each relevant attribute) of the item in 132 of fewer data fields, and that the formats of each unit record be identical.

In forest inventories the relation between the objects actually observed and the statistical sampling units may vary from one sampling plan to another. Generally, the statistical sampling unit is a plot of ground of given dimensions, whereas at least some of the sampling-unit attributes can be actually observed only on a subdivision of the sampling unit such as a point or a tree. Consequently, the input data for a sampling unit (the object of observation for purposes of compilation) are a set of unit records in which the actual observations on each subdivision of the sampling unit are recorded. The set may contain any number of unit records not exceeding 160. Other relations between objects actually observed and statistical sampling units reduce to special cases of the general case just described and can be handled accordingly. In short, the inventory data input is always handled as a simple itemized list of observed objects. What these objects are and how the data will be processed depend upon the sampling plan and field procedures under which the data were obtained.

I-D. Compilation Instruction Inputs

The compilation instructions describe the particular data-processing job at hand. The instruction inputs are treated by the system as data, but they are a special kind of data. They are incorporated into the system in such a way as to complete and/or modify it as required for the job to be done. To a large extent, this operation is done automatically. Because of the way they are handled, the instruction inputs may be considered as an integral part of the system once they have been presented to it, but they may also be changed at will if the need arises.

The instruction inputs describe: (1) the outputs required of the system; (2) the data inputs to the system; (3) the measurement checks and calculations required to obtain values of all relevant attributes of the sampling units; (4) the rules whereby the set of unit records representing the sampling unit are transformed to a set of tables for the sampling unit that have the same format as the output tables; and (5) the sampling design and estimating procedures to be followed in processing.

I-E. System Functions and Organization

The system is designed to produce output tables of resource statistics from the following types of inventory:

1. Complete (100-percent) coverage of sampling units in a survey unit.
2. Simple random sample of sampling units in a survey unit.
3. Systematic sample of sampling units in a survey unit, with random elements in sample selection.
4. Stratified random sample of sampling units in a survey unit, with known stratum weights.
5. Stratified random sample of sampling units in a survey unit, with stratum weights estimated from a primary sample.

Direct estimates of the resource statistics can be made from each of these inventory types. For the fifth type of inventory, several alternative means of indirect (ratio and regression) estimation are also provided. These have been designed primarily to accommodate the northeastern forest survey and will be described more fully in the discussion of that survey in part X.

The operations needed to make these estimates are grouped into subsystems, each covering a major phase of the processing. The result is an orderly sequential flow of information from the user to the system, through the successive processing steps and back to the user, as illustrated by the case of processing a single sample (fig. 1.) This configuration of the system is the normal one for a processing job, but variations of this arrangement may also be

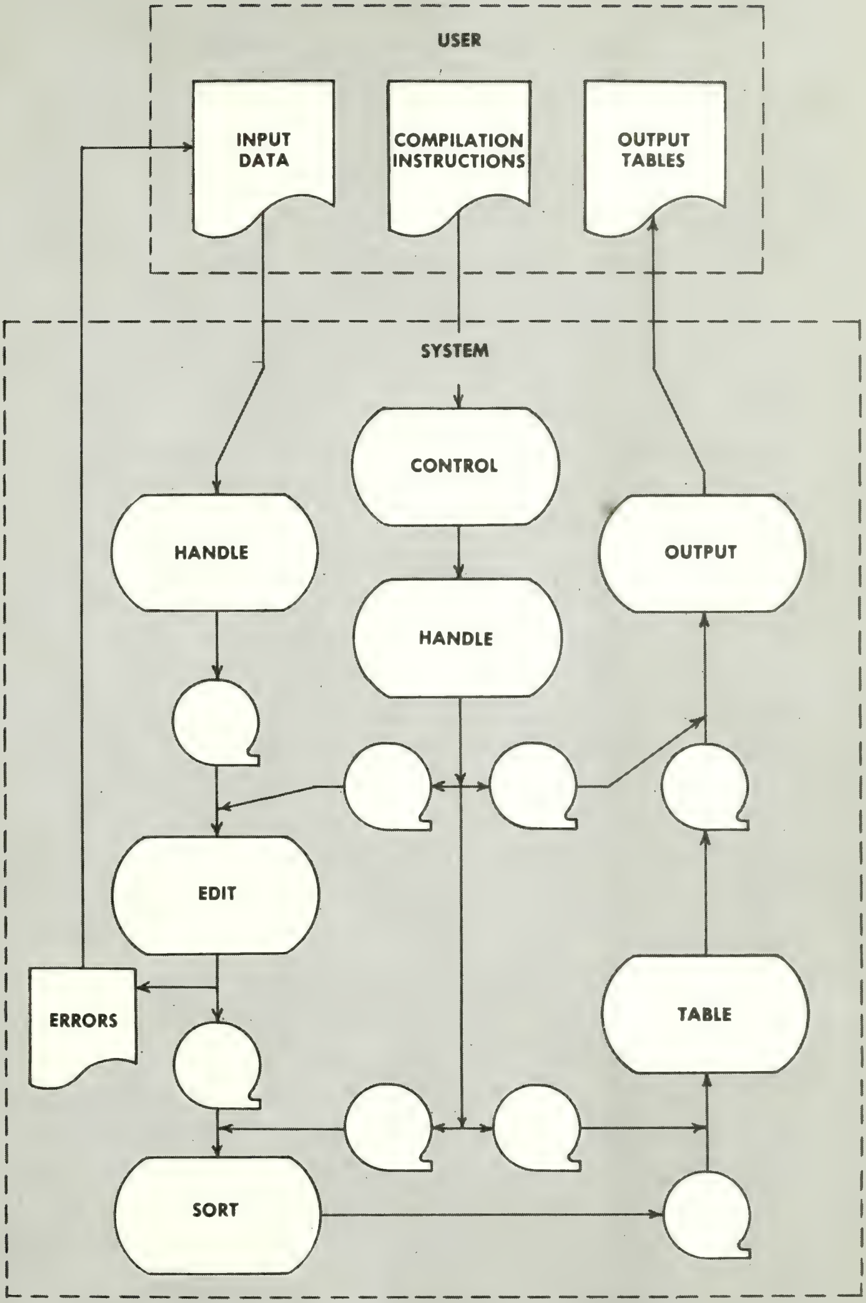

Figure 1.—System configuration for processing a single sample.

employed. System configurations will be discussed directly after the discussion of the functions of each subsystem (I-J).

The functions of the CONTROL subsystem are to accept compilation instructions from the user, to translate the instructions into appropriate system configurations and control data for each stage of processing, and to monitor and supervise the entire processing job. The only component of this subsystem is a person who is thoroughly acquainted with forest-inventory procedures and with the operations of this system.

The principal function of the HANDLE subsystem is to handle information (both inventory data and control data) within the system. It performs such operations as the punching, verifying, rearranging, and taping of information for later use, and the storage and retrieval of such information in master files. The components of the subsystem are: (1) people who operate machines and perform clerical work; (2) hardware such as key punches, verifiers, and an IBM 1401 System; and (3) software (computer programs) for the latter, to be used in maintaining the master files.

It is important to note that these two subsystems are presented as conceptual rather than as matters of fact. The functions encompassed by these subsystems must be performed, but because the principal components are people whose salaries must be paid and machines that must be rented, the user or his organization is responsible to set them up. The particular configurations of these systems will depend upon the volume of work, the cost limitations, and so forth.

The remaining subsystems are composed primarily of computer programs. The heart of each subsystem is a computer program tailored to the needs of the system and bearing the same name as the subsystem. The programs have been written in FORTRAN IV for use with Yale University's IBM 7094/7040 Direct Coupled Computer System.[2] The subsystems are operational under the IBSYS Monitor and will run with little or no modification on other computers that accept FORTRAN IV, have binary arithmetic, a 32K core (minimum of 36 bits per word), and 5-tape drives or equivalent input-output devices.

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[2] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

I-F. The EDIT Subsystem

The EDIT subsystem functions as a unit-record processor (fig. 2). It processes one record at a time from the data input list previously described. Its functions are to check the values in data fields or groups of data fields in each record for validity or reasonableness, to generate values for additional data fields from input values of other data fields, and to provide summaries of sets of records consisting of the sums over the sets of values in one or more data fields.

These functions are performed by a set of pre-programmed operations. For each check or calculation to be performed on a record, the user selects an appropriate operation, designates the data fields to which it is to be applied, and furnishes the numerical operators required.

The outputs from the subsystem are of three kinds: (1) the correct, augmented records, which are put on a magnetic tape file; (2) error messages identifying incorrect records and on which the types of error are printed; and (3) data-field summaries, which are both printed and punched in the form of tables. When error records have been corrected, they are passed through the subsystem a second time and, if they pass the checks, they are added to the correct record tape file and the data field summary outputs.

I-G. The SORT Subsystem

The SORT subsystem is a general IBM system which is used to arrange the correct record output from the EDIT subsystem in the order required for subsequent processing. The records for a sampling unit are arranged in sets and ordered within the sets, if necessary. These sets are in turn arranged into groups for each sample stratum and ordered within the groups if necessary. The sample stratum groups are, in turn, grouped into survey unit groups (arbitrary subdivisions of a geographical area) which, in turn, are ordered within the geographical area. This exhausts the hierar-

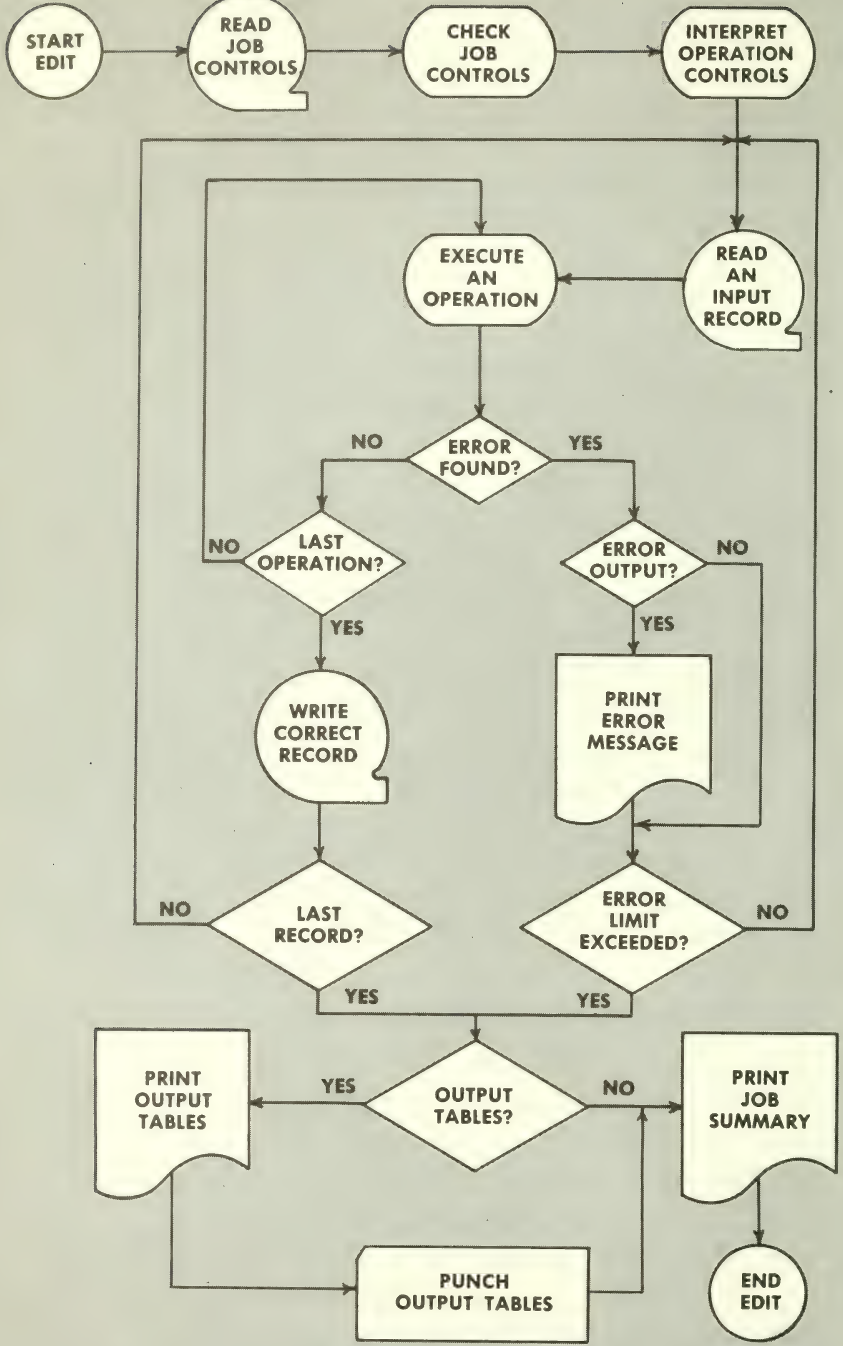

Figure 2.—A generalized flow chart of EDIT.

chy of records that are available in the system. The levels that are recognized depend upon the type of inventory.

I-H. The TABLE Subsystem

The TABLE subsystem has three primary functions: (1) to transform the data input for each sampling unit into a set of tables with the same format as the final output tables; (2) to sum these sets of tables, cell by cell, over all the sampling units in the sampling-unit set; and (3) to compute output statistics for the tables of each sampling-unit set (fig. 3). Four options, or alternative combinations of output statistics, are available:

1. Sums of tabular sampling-unit values over all sampling units in the sampling-unit set.
2. Arithmetic means of tabular sampling-unit values over all sampling units in the set of sampling units.
3. Arithmetic means and their variances of tabular sampling-unit values over all sampling units in the sampling-unit set.
4. Arithmetic means, their variances, and covariances between the means of each table cell and the mean over all cells in the tables.

The last option is designed primarily for the northeastern forest survey to use in estimating the variance of ratio estimates. (See part X in this series).

The data inputs to this subsystem are simply the ordered sets of sampling-unit inputs, each consisting of an ordered set of unit records, as described under the SORT subsystem.

Processing proceeds one sampling unit at a time. The critical function of transforming the sampling-unit input data to output tables is performed by a set of pre-programmed operations. The required tables are formed sequentially for each sampling unit. In general, table entries are made in the following manner: The value in some data field (designated in the compilation instructions) is entered into the table at a location determined as a function of the values in one or two other data fields of that record. The functions and the data fields to be used in determining the location of an entry are also obtained from the compilation instructions.

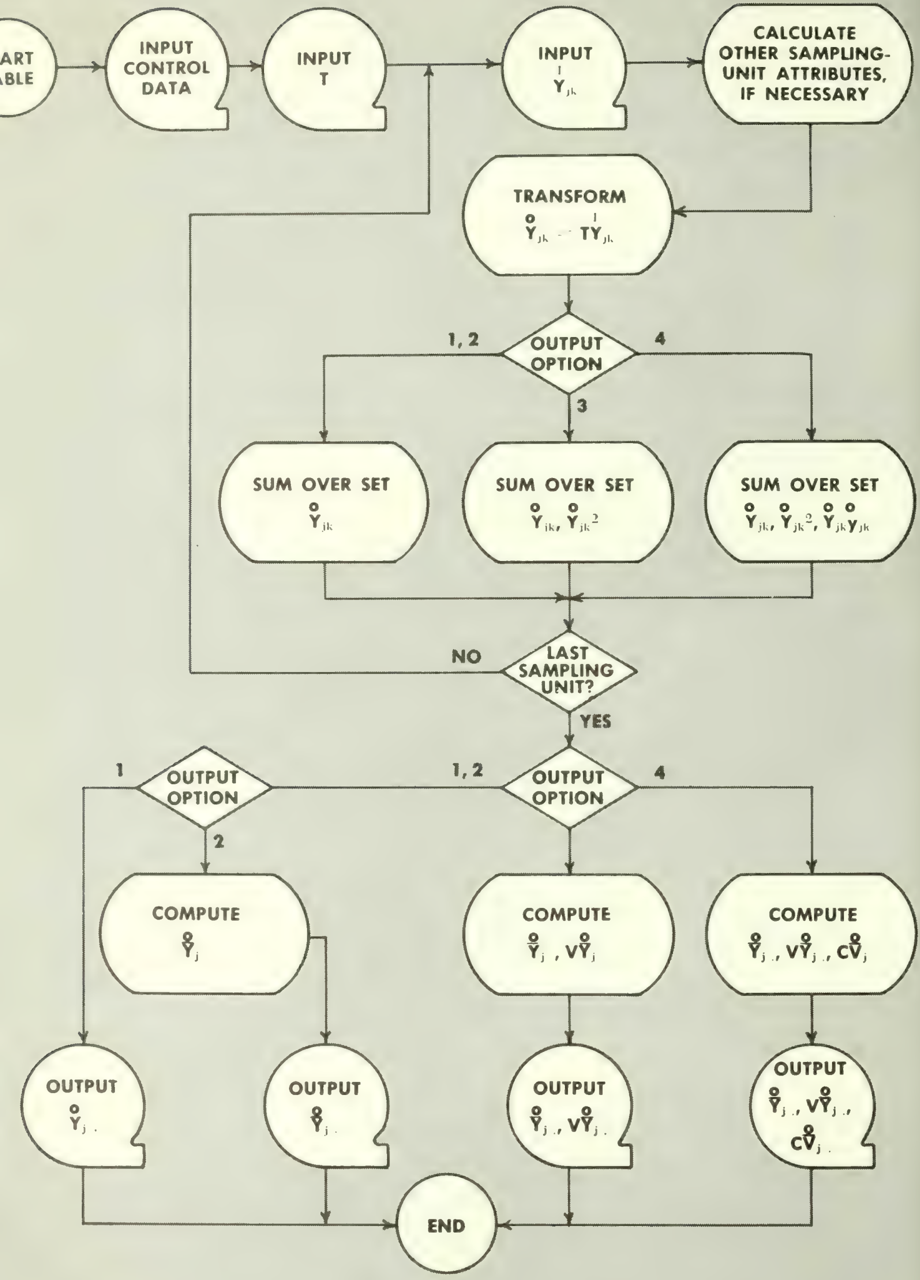
ART
ABLE
INPUT CONTROL DATA
INPUT T
INPUT $\overset{\prime}{Y}_{jk}$
CALCULATE OTHER SAMPLING-UNIT ATTRIBUTES, IF NECESSARY
TRANSFORM $\overset{o}{Y}_{jk} \leftarrow T\overset{\prime}{Y}_{jk}$
OUTPUT OPTION
1, 2
3
4
SUM OVER SET $\overset{o}{Y}_{jk}$
SUM OVER SET $\overset{o}{Y}_{jk}, \overset{o}{Y}_{jk}^2$
SUM OVER SET $\overset{o}{Y}_{jk}, \overset{o}{Y}_{jk}^2, \overset{o}{Y}_{jk}\overset{o}{y}_{jk}$
LAST SAMPLING UNIT?
NO
YES
OUTPUT OPTION
1, 2
4
OUTPUT OPTION
1
2
COMPUTE $\overset{o}{\bar{Y}}_{j}$
COMPUTE $\overset{o}{\bar{Y}}_{j}, V\overset{o}{\bar{Y}}_{j}$
COMPUTE $\overset{o}{\bar{Y}}_{j.}, V\overset{o}{\bar{Y}}_{j.}, C\overset{o}{V}_{j}$
OUTPUT $\overset{o}{Y}_{j.}$
OUTPUT $\overset{o}{\bar{Y}}_{j.}$
OUTPUT $\overset{o}{\bar{Y}}_{j.}, V\overset{o}{\bar{Y}}_{j.}$
OUTPUT $\overset{o}{\bar{Y}}_{j.}, V\overset{o}{\bar{Y}}_{j.}, C\overset{o}{V}_{j.}$
END

Figure 3.—A generalized flow chart of TABLE.

i = Subscript for the ith element of a vector.

j = Subscript for the jth sample stratum.

k = Subscript for the kth sampling unit.

T = A set of rules (transform) whereby the elements of the sampling-unit attribute vectors (inputs), $\overset{I}{Y}_{jk}$, are redistributed to form the sampling-unit attribute vectors (output tables), $\overset{o}{Y}_{jk}$.

$\overset{I}{Y}_{jk}$ = An input vector containing a sampling-unit attribute (a data field from the input data matrix for a sampling unit).

$\overset{o}{Y}_{jk}$ = A sampling-unit attribute vector (output table) which represents a summary of the input vector, $\overset{I}{Y}_{jk}$, for that attribute.

$\overset{o}{y}_{.jk}$ = The sum (total inventory) of the elements of the sampling-unit attribute vector (output table), $\overset{o}{Y}_{jk}$.

$\overline{\overset{o}{Y}}_{j.}$ = An attribute output vector (table), containing the arithmetic means for the sampling-unit attribute vectors, $\overset{o}{Y}_{jk}$, for the stratum.

$V\overline{\overset{o}{Y}}_{j.}$ = The variance of $\overset{o}{Y}_{j.}$.

$C\overline{\overset{o}{V}}_{j}$ = An output vector (table), containing the mean covariances of $\overset{o}{Y}_{jk}$ with $\overset{o}{y}_{.jk}$.

Provision is also made in the subsystem for excluding certain unit records from the tables, and for making more than one entry in a table for each unit record.

I-I. The OUTPUT Subsystem

The primary function of the OUTPUT subsystem is to produce the complete, fully labeled output tables of resource statistics describing the population of sampling units in each survey unit given as input (fig. 4). There are six ways in which these tables may be produced:

1. Tables for one or more sets of sampling units that represent the survey unit may be read in, added together, and printed. The input for this alternative is the output from the first option of the TABLE subsystem (or its equivalent).
2. Tables for a set of sampling units representing the survey unit may be read in, multiplied by an appropriate expansion factor, and printed, with standard errors. The standard errors are computed for a simple random sample. The input for this alternative is the output from the third option and the expansion factor.
3. Tables for each sample stratum within the survey unit may be read in, weighted by stratum size, summed, multiplied by appropriate expansion factors, and printed, with standard errors. The sampling errors are computed for a stratified random sample with known stratum weights. The inputs for this alternative are the output from the third option, the stratum weights, and the expansion factors.
4. Tables for each sample stratum within the survey unit may be read in, weighted by stratum size, summed, multiplied by appropriate expansion factors, and printed, with standard errors. The standard errors are computed for a stratified random sample with stratum weights estimated from primary sample. The inputs for this alternative are the outputs from the third option, the estimated stratum weights, and the expansion factors.
5. Tables for each sample stratum within the survey unit are read in, converted to ratios (ratios of the values in the total cells of

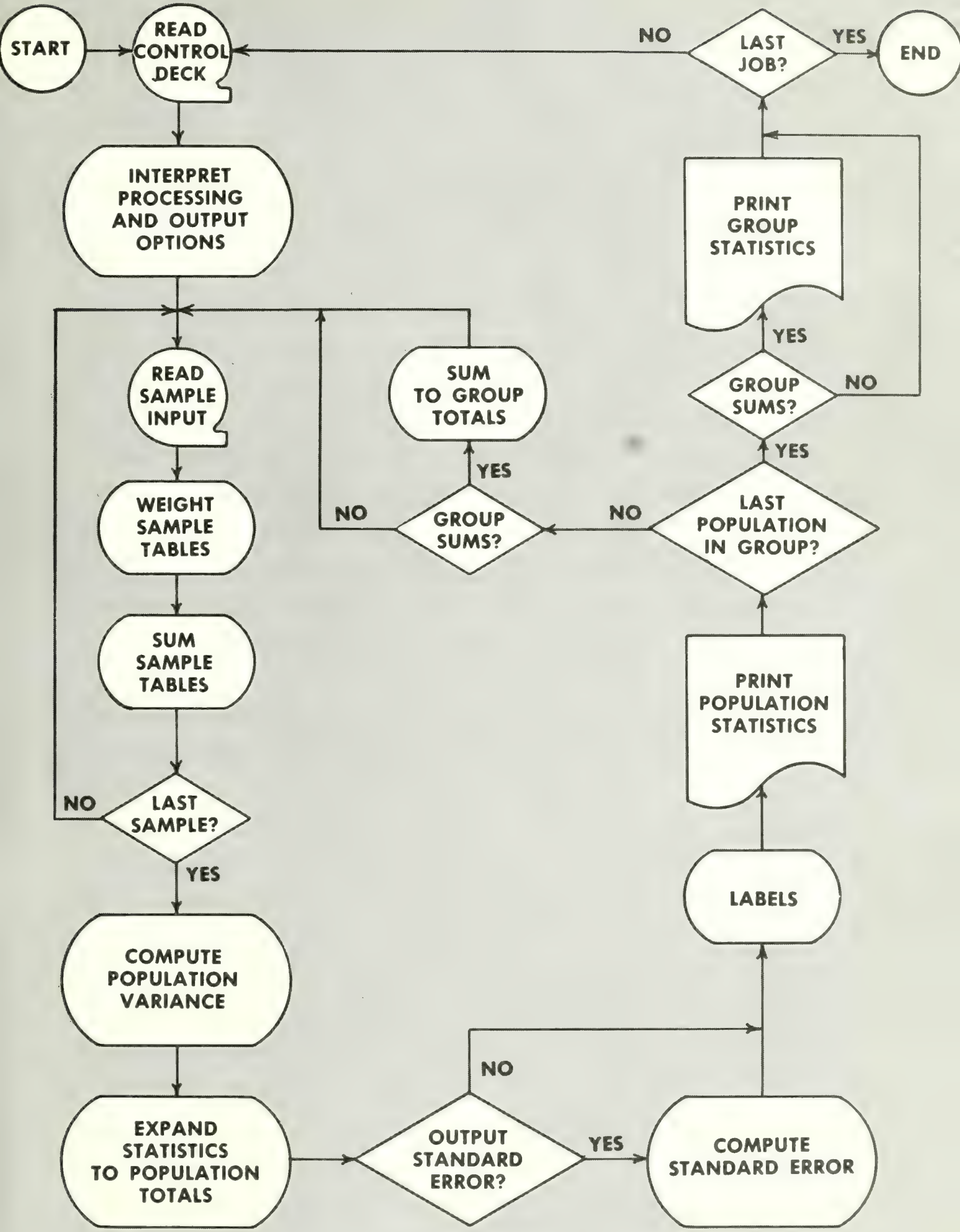

Figure 4.—A generalized flow chart of OUTPUT.

the tables), multiplied by independent estimates of the table totals, weighted by stratum size, summed, multiplied by appropriate expansion factors, and printed, along with standard errors. The standard errors are computed for a separate stratified ratio estimate, including estimated stratum weights. The inputs for this alternative are the outputs from the fourth option, the stratum weights, the stratum totals for each table, and appropriate expansion factors.

6. Tables for each sample stratum within the survey unit are read in, weighted by stratum size, summed over strata, converted to ratios (ratios of the values in the total cells of the tables), multiplied by independent estimates of table totals and appropriate expansion factors, and printed, with standard errors. The standard errors are computed for a combined stratified ratio estimate, with estimated stratum weights. The inputs for this alternative are the outputs from the fourth option, the estimated stratum weights, the independent estimates of the survey-unit totals, and the expansion factors.

In addition to the survey-unit outputs just described, two other kinds of outputs can be obtained from this subsystem. When two or more survey units are processed successively in the same pass, the table estimates and their variances can be accumulated over the group of survey units, standard errors for the group can be computed, and the results for the group can be printed in the same format as the survey-unit results. Alternatively, when only one survey unit is processed in a pass, the table inputs can be used repeatedly with different weights, expansion factors, etc., to obtain estimates and sampling errors for any number of subdivisions such as counties of the survey unit. Again, the results are printed in the same format as the survey-unit results.

I-J. System Configurations

The system as described so far will accommodate most forest-inventory data-processing jobs. In some cases it may be possible to bypass some subsystems, such as EDIT and/or SORT. In some cases the data may be partially processed by other means, and only one subsystem may be needed. Either of these situations can be met, provided the necessary inputs are available. Any of the processing subsystems except OUTPUT can be used independently of the system as a whole.

On the other hand, some processing jobs may require more elaborate configurations of the system, usually based on multiples of the configuration shown in figure 1. For example, the northeastern forest survey uses three stratified ground samples in making its estimates, all with stratum weights estimated from primary photo samples.

A current sample is used to estimate total areas and total volumes, and to estimate ratios for the distribution of total inventories into the output tables. As already described, the ratios are estimated in the OUTPUT subsystem by either of two procedures: the ratios may be estimated stratum by stratum (separate ratio estimates) or from weighted means over all strata (combined ratio estimates). The latter procedure is currently being used in the northeastern forest survey.

The sample of the previous inventory is updated by a regression sample of remeasured plots to obtain another estimate of total areas and volumes. The two estimates of totals are then combined and used as multipliers with the tabular ratio estimates to obtain the final output tables of area and volume statistics. Although the ratios and totals are not strictly independent in this example the effect of covariance on the sampling errors is assumed negligible.

Finally, output tables of growth and mortality statistics are estimated directly from the regression sample.

Consequently, the system configuration for processing the northeastern forest survey (fig. 5) provides that each of two samples be passed through the processing steps shown in figure 1. It will be noted also that there are two additional subsystems in this configuration that are used to produce the estimates of total areas and volumes.

The TOTAL subsystem provides the means to produce independent estimates of the grand totals of each output table (max-

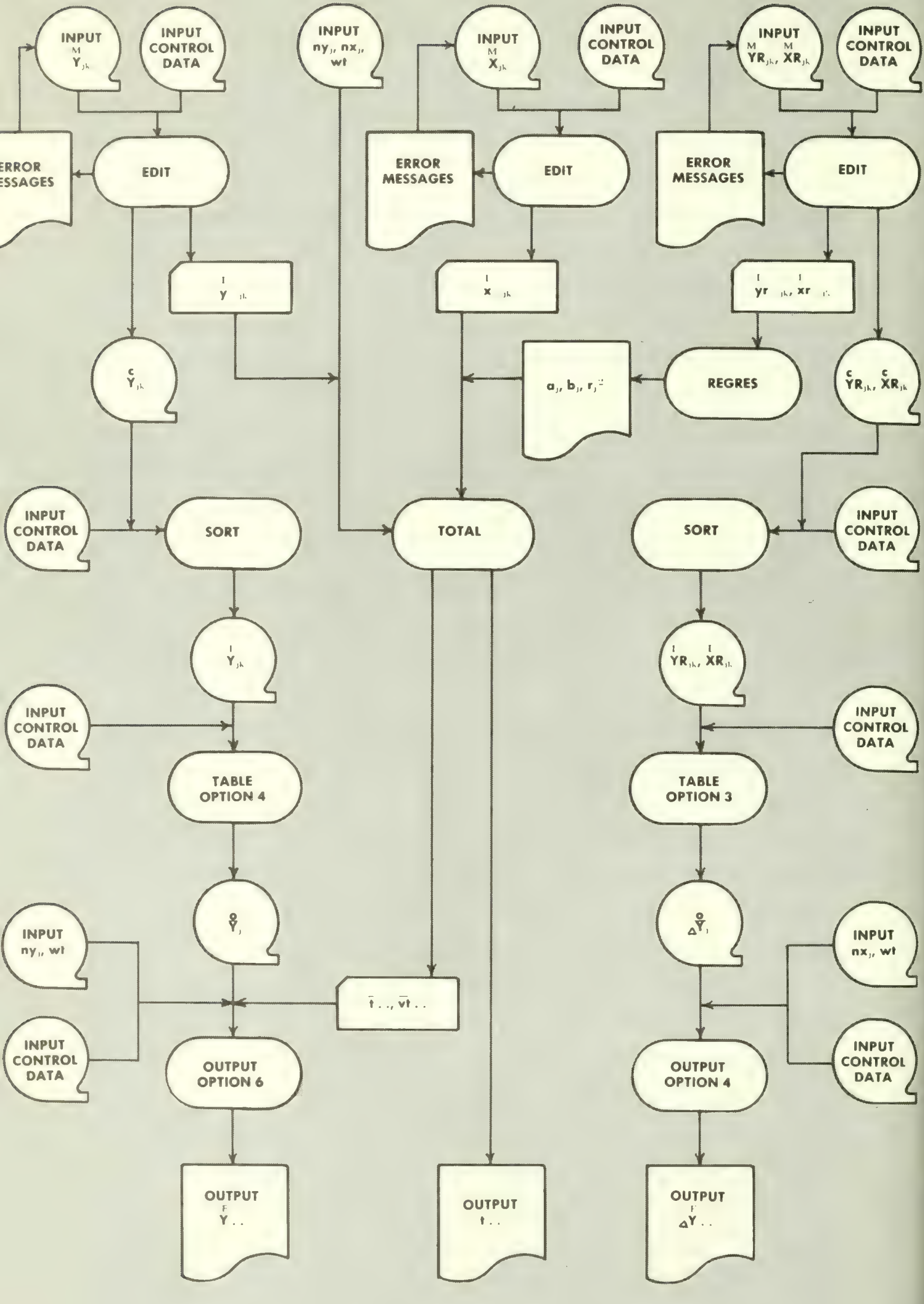
INPUT $\overset{M}{Y}_{jk}$
INPUT CONTROL DATA
INPUT ny_j, nx_j, wt
INPUT $\overset{M}{X}_{jk}$
INPUT CONTROL DATA
INPUT $\overset{M}{YR}_{jk}$, $\overset{M}{XR}_{jk}$
INPUT CONTROL DATA
ERROR MESSAGES
EDIT
ERROR MESSAGES
EDIT
ERROR MESSAGES
EDIT
$\overset{I}{y}_{jk}$
$\overset{I}{x}_{jk}$
$\overset{I}{yr}_{jk}$, $\overset{I}{xr}_{jk}$
$\overset{c}{Y}_{jk}$
a_j, b_j, r_j^2
REGRES
$\overset{c}{YR}_{jk}$, $\overset{c}{XR}_{jk}$
INPUT CONTROL DATA
SORT
TOTAL
SORT
INPUT CONTROL DATA
$\overset{I}{Y}_{jk}$
$\overset{I}{YR}_{jk}$, $\overset{I}{XR}_{jk}$
INPUT CONTROL DATA
TABLE OPTION 4
TABLE OPTION 3
INPUT CONTROL DATA
$\overset{o}{Y}_j$
$\Delta\overset{o}{Y}_j$
INPUT ny_j, wt
$\bar{t}_{..}$, $\overline{vt}_{..}$
INPUT nx_j, wt
INPUT CONTROL DATA
OUTPUT OPTION 6
OUTPUT OPTION 4
INPUT CONTROL DATA
OUTPUT $\overset{F}{Y}_{..}$
OUTPUT $t_{..}$
OUTPUT $\Delta\overset{F}{Y}_{..}$

Figure 5.—System configuration for Northeastern Forest Survey processing.

i = Subscript for the ith element of a vector.

j = Subscript for the jth sample stratum.

k = Subscript for the kth sampling unit.

$\overset{M}{Y}_{jk}$ = Mixed (unsorted) sets of sampling-unit data input records from the current sample.

$\overset{C}{Y}_{jk}$ = Correct but unsorted sets of sampling-unit data input records from the current sample.

$\overset{I}{Y}_{jk}$ = Correct and sorted sets of sampling-unit data input records from the current sample.

$\overset{O}{Y}_{j\,.}$ = Sets of output tables containing means and their variances over sets of sampling units of sampling-unit attributes from the current sample.

$\overset{F}{Y}_{..}$ = Sets of output tables containing the area and volume statistics required, with sampling errors.

$t_{..}$ = A set of final estimates of output table totals, with sampling errors.

${}_{\Delta}\overset{F}{Y}_{..}$ = Sets of output tables containing the growth and mortality statistics required, with sampling errors.

X_{jk} = Sets of sampling-unit data input records from the initial inventory sample.

$YR_{jk}, XR_{jk.}$ = Paired sets of sampling-unit data input records from the regression sample (remeasured plots).

$\overset{I}{Y}_{.\,jk}$ = Set of output-table totals for each sampling unit.

$x_{.\,jk}$ = Set of values of independent regression variables corresponding to output-table totals for each sampling unit.

ny_j, nx_j = Sets of sample stratum weights from the primary samples.

wt = Expansion factor or size of survey unit (total number of sampling units).

imum of 40 tables) from stratified random samples, with stratum weights estimated from primary samples. Although these are intended primarily for use with the tabular ratio estimates, they may also be useful in their own right when full output tables are not required or when estimates of total inventory are needed very quickly. Four alternatives are available, each with a corresponding set of sampling errors:

1. Separate stratified regression estimates.
2. Combined stratified regression estimates.
3. Stratified direct estimates.
4. Combination of two independent estimates made by any of the previous alternatives.

The data inputs are the data-field summaries of volumes and area classes for each sampling unit of a sample obtained as special output from the EDIT pass of each sample. Either one or two samples may be processed at one time, but the resulting estimates can be combined only if the two independent estimates are processed in one pass.

The REGRES[3] subsystem provides the means to obtain stratum-by-stratum estimates of regression parameters and/or ratios, and their sampling errors for the totals of up to 40 output tables. The data inputs are the data-field summaries of paired volumes and area classes for each sampling unit in the regression sample (remeasured plots) obtained as special output from the EDIT subsystem.

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[3] REGRES: an abbreviation for "regression sample."

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

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Introduction

THIS list of publications was compiled as reference material for the forester, forestry researcher, and forestry student. It contains references to 1,436 publications by staff members of the Northeastern Forest Experiment Station and their cooperators during the period 1950-65. It does not include publications of Central States projects that were incorporated into the Northeastern Station research program in the reorganization of March 1966.

Earlier publications of the Northeastern Station, since the establishment of its predecessor, the Allegheny Forest Experiment Station, in 1923, are listed in a bibliography published in 1950 (Northeastern Forest Experiment Station, Station Paper 33). Though now out of print, this bibliography may still be available in libraries.

This new bibliography is a simple listing of titles, arranged alphabetically by authors. Length precludes including annotations. And because the many fields of research engaged in by the Station so often intermingle and overlap, no attempt has been made to sort out the publications by subject matter.

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UNIVERSITY

A look at
KENTUCKY'S LUMBER INDUSTRY

by Owen W. Herrick

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RICHARD D. LANE, DIRECTOR

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A look at KENTUCKY'S LUMBER INDUSTRY

◆

THIS report provides a look at Kentucky's lumber industry as it was in 1962. The influences of sawmill size and geographic location were analyzed to explain differences in operating and marketing practices.

Three geographic regions of the State were recognized: the Eastern Highlands, the Western Plateau, and the Bluegrass region (fig. 1). These regions are distinguished by physiographic features ranging from the heavily forested and rugged topography of the Highlands to the gentle terrain and lightly forested farmland of the Bluegrass.

For analysis, sawmills were classified according to annual lumber production as small (0 to 499 thousand board feet), medium (500 to 2,999 thousand board feet), or large (3 million + board feet).

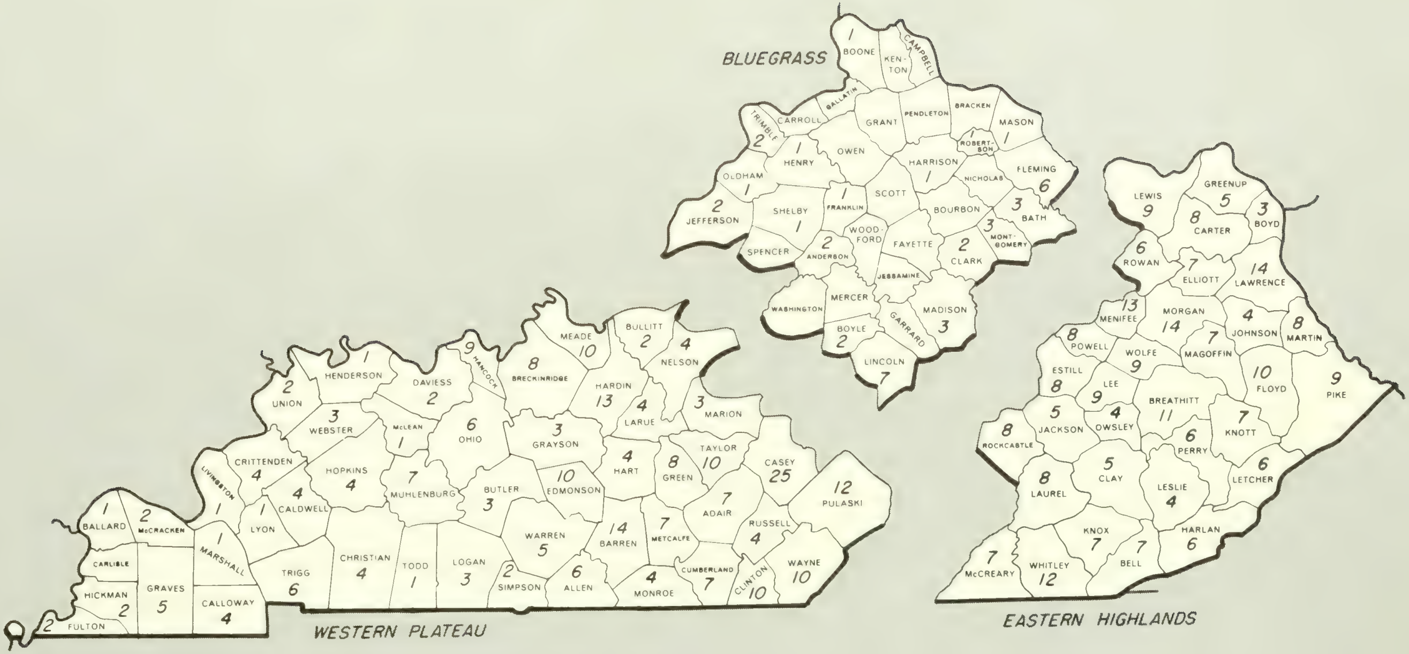
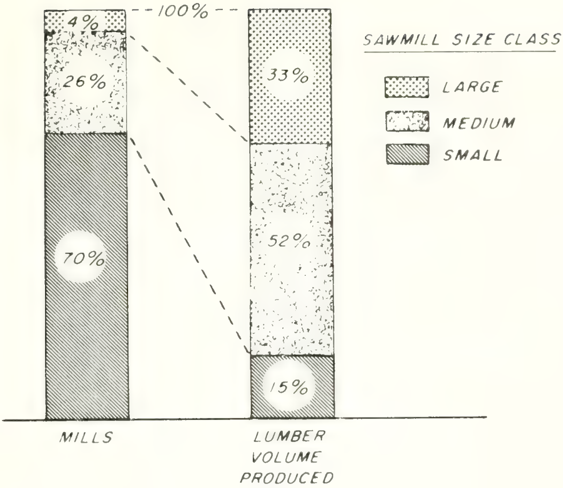


Figure 1.—The regions of Kentucky, showing number of active sawmills, by county, in 1962.

Figure 2.—Percentage distribution of sawmill firms and lumber output in Kentucky, by sawmill size-class, 1962.



INDUSTRY TRENDS

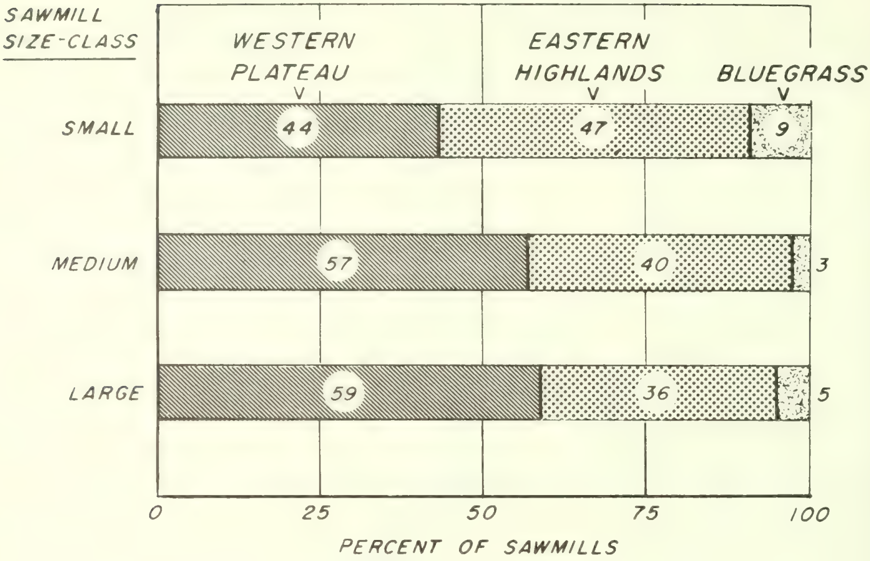
Between 1942 and 1962, the number of active sawmills in Kentucky decreased 70 percent—from 1,863 mills to 566. Decline was greatest among small sawmills (almost 75 percent) ; and the proportion of small mills among all mills in the State is now 17 percent less than before. Medium and large sawmills also declined in number, but their proportion of the total more than doubled. This parallels a general sawmill industry trend toward concentration of lumber production at fewer but larger mills.

Large sawmills comprised only 4 percent of the 566 operating mills in the State, yet they produced one-third of Kentucky's 1962 lumber output(fig. 2). By contrast, small sawmills comprised 70 percent of all the firms but produced only 15 percent of the total lumber output.

This same production pattern was found in all three regions of the State. In each region small sawmills represented a major portion of firms, but accounted for a minor portion of lumber output —ranging from a low of 12 percent of total lumber output in the Western Plateau to a high of 25 percent in the Bluegrass region.

The distribution of sawmills by size-class differed across the State. The Eastern Highlands region had more small sawmills than other regions, while medium and large sawmills were most numerous in the Western Plateau region (fig. 3).

Figure 3.—Sawmill size-class composition in Kentucky, by region, 1962.



ANNUAL OPERATING PERIOD

The average number of days operated annually differed between sawmill size-classes in each region by about the same proportion. For each day that small sawmills operated, medium mills operated about 3 days and large mills operated 4½ days (table 1). In many cases crews at the small mills not only operated the mill but also harvested the sawlogs, thereby limiting the number of days that the mill itself was active.

Sawmills in the Eastern Highlands operated fewer days during the year than mills in the other regions. Traditional work habits, firm-management characteristics, and weather probably contributed most to regional differences in the annual operation period.

TIMBERLAND OWNERSHIP

Almost 40 percent of the sawmill operators in Kentucky owned timberland in 1962. More operators of medium sawmills owned timberland than did owners of sawmills of other sizes. Acreage owned increased with sawmill size-class, from an average of 210

Table 1.—*Average number of days operated per year, by region and sawmill size-class*

Region	Sawmill size-class		
	Small	Medium	Large
Western Plateau	55	181	250
Eastern Highlands	46	139	205
Bluegrass	57	187	—
All regions	51	165	230

acres for small mills to 2,994 acres for large mills. The average ownership was 405 acres.

A higher percentage of sawmill operators in the heavily forested Eastern Highlands owned timberland than did operators in the other regions. However, the average acreage held by one individual was greatest in the less-timbered Bluegrass region.

RAW-MATERIAL PROCUREMENT

Source of Raw Material

More than half the sawlogs used by Kentucky sawmills were purchased on the stump. Sawlog purchase from a timberland owner or logger was the other important form of raw material procurement. Together these two sources provided 95 percent of the industry's raw material. Although important to certain sawmills, other wood sources, including sawlogs cut from timberland owned by mill operators and logs brought to mills for custom sawing, were minor in the total industry supply. A similar procurement pattern occurred in the Eastern Highlands and Western Plateau regions of the State (fig. 4). However, in the less-timbered Bluegrass region less than one-third of the raw material was purchased on the stump and about half was purchased as sawlogs.

Raw-material procurement was about evenly divided between stumpage and sawlog purchases at the medium and large mills. However, at small mills stumpage accounted for almost two-thirds of raw material procurement; sawlog purchases, one fourth.

Working Radius

Larger sawmills tended to bring logs from greater distances. For example, operators of medium sawmills covered twice the

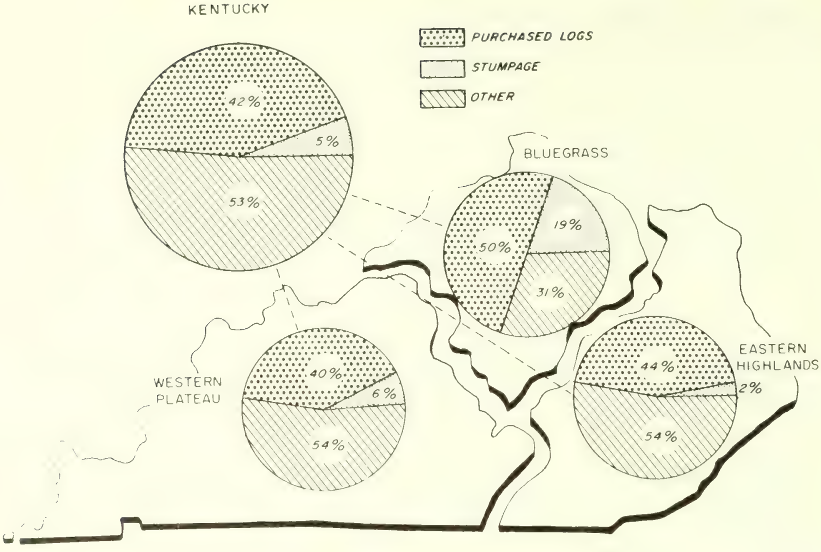


Figure 4.—Percent of raw-material volume by procurement method, for Kentucky and regions, 1962.

working radius of small mills, and large mills extended this distance more than 3½ times (table 2).

Working radius also differed by region, averaging 17 miles in the Eastern Highlands, 24 miles in the Western Plateau, and 32 miles in the Bluegrass region. As would be expected, hauling distances were shorter in heavily forested rugged terrain such as the Eastern Highlands than in lightly forested areas with gentle terrain favorable to hauling as in the Bluegrass.

Sawlog Measurement

The Doyle log rule was used most commonly throughout the State, but the International ¼-inch rule was used at some mills in the Eastern Highlands and Bluegrass regions (table 3). Timber sales from the Daniel Boone National Forest, which specify use of International ¼-inch log rule, undoubtedly influenced its use in these regions. Other measures, including mill or lumber tally and the cedar log scale, were used in the Western Plateau region and at small sawmills (table 3).

PRODUCTS MANUFACTURED

The principal income-producing product of most Kentucky sawmills is either graded lumber or local-use lumber. Graded lumber is inspected and sold according to accepted lumber-grade rules, such as those of the National Hardwood Lumber Association, and the Southern Pine Association. Selling lumber graded under these rules provides access to national markets. Ungraded or local-use lumber, on the other hand, is normally sold in small quantities directly to local users. In 1962 more than four-fifths of all Kentucky sawmill firms obtained a major portion of their annual income from these products. The remainder received the major part of their income from (1) pallet, blocking, and crating lumber; (2) mining material; or (3) sawed posts, ties, and treating material (fig. 5).

Because of local markets, regional differences occurred in the percentage of firms obtaining their major income from certain sawmill products. For example, local-use lumber was the principal income-producing product at sawmills in the Bluegrass region. And graded lumber was the main product at mills in the other

Table 2.—*Percent of sawmills drawing wood from various distances, by sawmill size-class*

Sawmill size-class	Working radius (miles)					Average distance
	0-4	5-24	25-49	50+	Total	
			Percent			*Miles*
Small	12	73	11	4	100	15
Medium	2	36	44	18	100	30
Large	0	13	25	62	100	53

Table 3.—*Percent of sawmills using various log rules, by sawmill size-class*

Sawmill size-class	Log rule		
	International ¼-inch	Doyle	Other
Small	7	82	11
Medium	8	89	3
Large	11	89	—
All mills	8	84	8

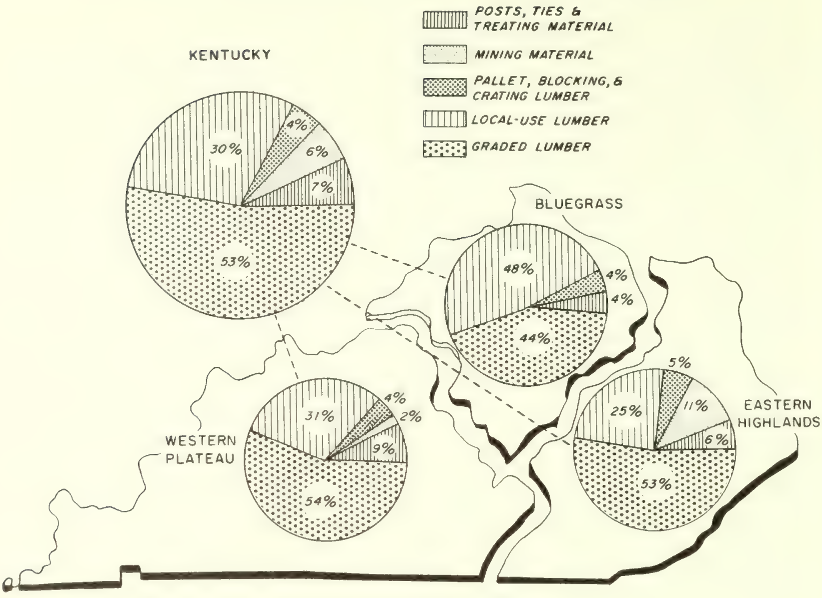


Figure 5.—Percent of sawmill firms according to principal income product, by regions and State, 1962.

two regions of the State. Income from production of mining material played a more important role in the Eastern Highlands, as did incomes from posts, poles, and treating material in the Western Plateau.

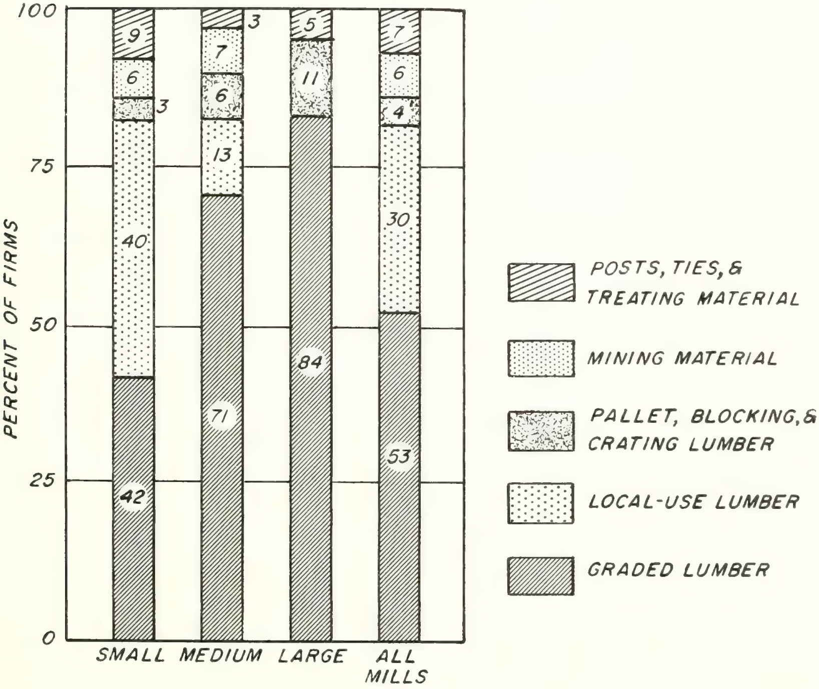
As expected, more of the larger mills produced graded lumber and pallet, blocking, and crating lumber than did smaller mills, which mainly produced local-use lumber (fig. 6). About the same portion of small and medium sawmills produced mining material; but as with posts, ties, and treating material, there was little direct relationship to mill size. For these products, the local demand situation was of greater influence than mill size.

SAWMILL RESIDUES

Kentucky's sawmills utilized 40 percent of their mill residues (slabs, edgings, and trim waste). Some of this material was used for fuelwood, some for conversion into wood chips, and some for miscellaneous uses such as mulch and fuel for tobacco-bed burning (fig. 7).

Utilization of sawmill residues depended largely upon local demand for such material and the size of the sawmill. Operators of small portable sawmills located on timber-sale areas had little opportunity to utilize residues profitably. Preventing the accumulation of wood waste from interfering with the mill operation was often their main concern. Furthermore, ease of public access to a sawmill appeared to influence consumption of wood residue for fuel and other local uses. Accordingly use of fuel wood and other local products was proportionately greater in the Bluegrass and Western Plateau regions, where sawmills are more accessible than in the Eastern Highlands. Wood chips were the main use for mill residue in the Eastern Highlands region, where the smallest proportion of sawmill residue was used.

Figure 6.—Sawmills classified by major income product according to mill size-class, 1962.



LUMBER MARKETING

Lumber output can be separated into (1) nonmarket production and (2) market production. Nonmarket production is lumber produced by the sawmill operator for his own use, or lumber that is custom sawed. These production activities involve no change in ownership of the lumber.

Ninety-four percent of all lumber produced in Kentucky in 1962 entered market outlets. This high proportion reflects the influence of the medium and large mills, which produced most of the State's lumber and placed almost all their lumber on the market (fig. 8).

Nonmarket lumber production was greatest in the Bluegrass region, where it accounted for almost one-fifth of the annual lumber output—reflecting the region's large proportion of small sawmills doing custom sawing primarily. In the Western Plateau and Eastern Highlands, nonmarket production represented only about 6 percent of total lumber output.

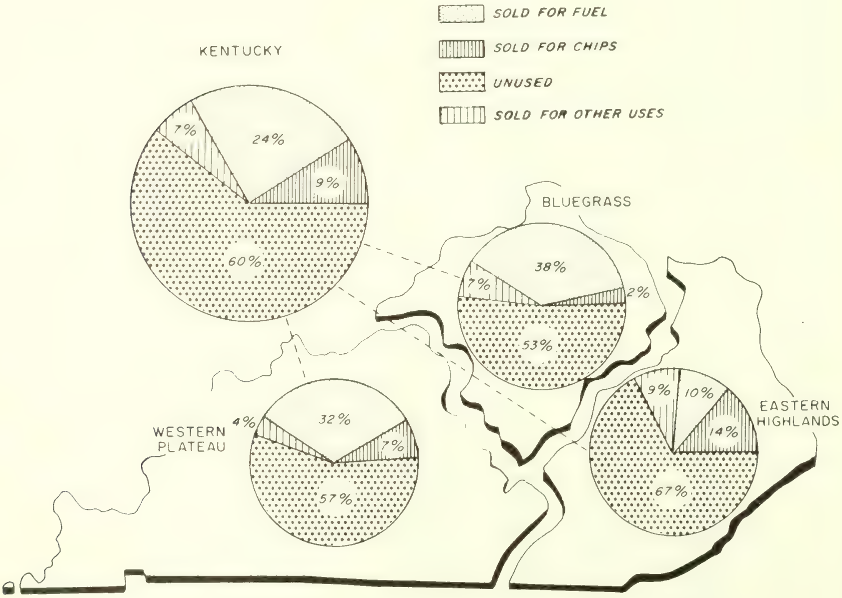
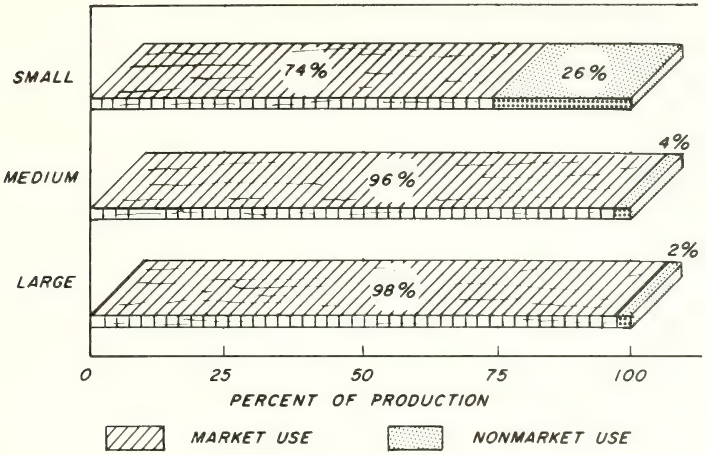


Figure 7.—Percent of sawmill residues utilized, by region and State, 1962.

Figure 8.—Percent of lumber production going to market and nonmarket use, by sawmill size-class, 1962.



CONCLUSIONS

If present trends continue, the number of small sawmills can be expected to decline. But continued demand for custom sawing suggests that they will not all disappear.

This predicted decline in the number of mills does not imply a decrease in Kentucky's lumber output. Rather, it suggests that the same amount or more lumber will come from fewer but larger firms. If this happens it is also likely that:

- Raw-material procurement will be feasible in areas more distant from sawmills.
- The amount of timberland owned by individual sawmill operators, as well as the number of sawmill operators owning timberland, will increase.
- The production of graded lumber will increase.
- Diversification into further manufacture and specialized products will increase.
- More sawmill residues will be used.

Such changes could lead to the growth of Kentucky's lumber industry and thus its entire economy.

Acknowledgment

THIS publication is based on data from a statewide timber utilization survey in 1962, conducted by the Kentucky Division of Forestry in cooperation with the former Central States Forest Experiment Station, U. S. Forest Service. All primary timber-product users in Kentucky were contacted by mail survey and by personal interview where necessary. Appreciation is expressed to the personnel of the Division of Forestry, Kentucky Department of Natural Resources, for collection of the data.

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Planning for TIMBER-TRACT DEVELOPMENT

by Robert Marty
and George R. Trimble, Jr.

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THE DEVELOPMENT PROBLEM

ONCE a forest owner has decided to develop his property for timber production,[1] his first concern is for the direction of development. This involves questions of species composition, method of management (even-aged or uneven-aged), and type of products to manage for. After these decisions are made, two basic problems arise.

The first problem is to determine the optimum level of development for the ownership. This involves the questions of how much growing stock to carry; how far to go in trying to establish, protect, and improve growing stock; and how much investment in roads and other physical improvement is justified. The second problem is to decide how fast to move toward this optimum level of development.

Development in Theory

The physical and biological characteristics of the timber tract determine how annual growth is related to growing-stock volume or basal area. Duerr (1960)[2]—has illustrated this relationship for a forest tract in southern Arkansas (table 1). Duerr's data show that, as growing-stock volume and value increase, the volume and value of annual growth rises as well, but at a decreasing rate.

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[1] We recognize that an owner may have objectives for his forest property other than timber production. He may wish to manage his woods partially or primarily for other outputs, in which case the development problems would be quite different.

[2] Duerr, William A. FUNDAMENTALS OF FORESTRY ECONOMICS. 579 pp., illus. McGraw-Hill, New York. 1960.

Table 1. — *Relationship between the volume and value of growing stock and of annual growth for a selection forest on a good site in southern Arkansas*[1]

(All values on a per-acre basis)

Growing stock		Annual growth		Marginal increments			
Volume	Value	Volume	Value	Added annual growth	Value of added annual growth	Cost of added growing stock	Rate of return
Board feet	*Dollars*	*Board feet*	*Dollars*	*Board feet*	*Dollars*	*Dollars*	*Percent*
5,000	210.00	486	21.46				
				66	3.54	47.30	7.5
6,000	257.30	534	25.00				
				58	3.20	49.20	6.5
7,000	306.50	592	28.20				
				46	2.86	50.90	5.6
8,000	357.40	638	31.06				
				38	2.48	52.70	4.7
9,000	410.10	676	33.54				
				28	2.08	54.60	3.8
10,000	464.70	704	35.62				
				18	1.64	56.30	2.9
11,000	521.00	722	37.26				

[1] After Duerr (1960), page 122.

The rate of return earned by increasing growing-stock levels can be determined by comparing the value of the additional growing stock with the value of the additional annual growth it generates. For example, table 1 shows that when the growing stock level is increased from 6,000 to 7,000 board feet per acre, growing-stock value will rise by $49.20 per acre, and 58 board feet per acre will be added to annual growth, with a value of $3.20. So this particular addition to the growing-stock investment yields a 6.5 percent rate of return.

By raising the level of growing stock, the owner of a timber tract may receive an additional increment in annual output. As the growing-stock investment is increased, a point is eventually reached at which the rate of return on the next increment in growing stock will have fallen to an unacceptable level. This point marks the optimum level of investment in growing stock. Owners differ on what constitutes an acceptable rate of return according to their current financial needs. This means that identical timber tracts may have contrasting optimum levels of growing stock for different owners.

Foresters can influence the value of growing stock and of annual production by means other than simply altering growing-stock volumes. They can change its composition as well. The type and frequency of harvest cutting, and the amount of effort expended in establishing, protecting, and tending young trees all influence the amount and value of the annual growth available from any given volume of growing stock, and the value of that growing stock as well.

Timber-management activities are designed to increase average tree value by favoring trees of more valuable species and better grades. Another objective of management is to increase growth rates (and to some extent quality increment) through spacing control. And, by timely cutting and stand-improvement measures, cull and mortality may be reduced. Investments in physical improvements also can influence the value of growing stock and of annual production. For example, roads make extraction less costly and so increase stumpage value.

So, instead of there being only one way to change the level of investment in the tract, there are many. All these investment paths

—increases in the size to which trees are grown, improvements in species composition and grade distribution, increases in spacing-control efforts, increases in establishment and protection practices, and increases in physical improvements—are available to the tract owner. In theory he would pursue each of these, and any others of which he may be aware, to the point where further investment would not yield an acceptable return. And at this point the owner would have exhausted all acceptable possibilities for tract development. No shift in investment from one path to another would improve his returns, and the tract would have been developed to the optimum.

Even in theory there can exist some limitations on the speed with which this optimum position is approached. Physical and biological factors often limit the pace at which stocking on a depleted tract can be built toward its optimum level and composition. And the imposition of a limit on the amount of new investment per year or decade can slow development.

Development in Practice

In practice the forest manager usually does not know the optimum level and mix of investment, but instead gropes toward this optimum position by trying out a little heavier (or lighter) stocking, by figuring out what a few more miles of road would cost and what they would buy, and by trying to determine whether to thin his poletimber or use some similar silvicultural practice.

This "cut-and-try" planning is often necessary because we do not have enough information to define the optimum development level for various kinds of timber properties and owners. And, in any situation a certain amount of adjustment and revision would be necessary because of the continual changes in timber-growing methods, cost of management, and product prices. Fertilization, for example, is a new timber-growing practice that eventually may cause profound changes in what is most advantageous in growing-stock levels.

In addition to the frequent changes in wage rates for labor, and frequent improvements in equipment and materials used in timber-growing, management costs are profoundly affected by going rates of interest. The availability of good investment opportunities elsewhere makes some woodland owners anxious to reduce growing-stock levels, and to forego the less-productive cultural measures for a quick profit. Changes in timber prices are frequent and sometimes severe, and this sort of change has often turned the casual ownership of timberland without thought of profit into a substantial and unexpected gain for the owner. New markets and changes in the relative value of various products also can change both the optimum species composition and the best growing-stock level.

The timber producer's response to changes in methods, costs, and prices is gradual and partial in practice, because these changes cannot be foreseen accurately. The timber producer is further delayed in adjusting to these changes because production responds slowly, even to prompt changes in management direction.

The practical response to the 30- to 80-year production lag is to concentrate on long-term trends in techniques, costs, and prices in development planning; to take advantage of unusually favorable market conditions by liquidating growing stock rapidly; and never to attempt under these circumstances actually to reach the optimum level of investment. Then, even if worst comes to worst, the marginal investments may not show too low a return.

Working Toward the Optimum

Assuming, then, that some optimum management program is at least envisioned, and that the whole development project is not aborted by markets much poorer or much better than expected, the question remains of how rapidly to work toward this optimum condition.

The speed with which investment for development proceeds depends to a great extent on the owner's investment resources. Some timber tracts are purchased on credit, and the new owner has to cut enough timber immediately to liquidate his debt. This owner may well end up with a tract even further from the optimum than when he purchased it. Other owners may buy a tract for the annual income it will provide. If they need less annual income than the value of annual growth, there is at least some margin for further investment that will eventually provide improved annual income for the owner. Investment proceeds most rapidly under the unusual circumstances where the owner can forego income for a decade or two and has spare cash to invest as well.

In practice the answer to how fast to move toward the optimum development is simply: as fast as you can afford to move.

AN EXAMPLE OF DEVELOPMENT PLANNING

The timber tract used here to illustrate development planning is a 600-acre compartment of the Fernow Experimental Forest operated by the U. S. Forest Service near Parsons, West Virginia.

The Sample Tract

This tract of timber is rather typical of the mountain hardwood stands on better-than-average sites found throughout the Appalachian region.

This area was first cut over about 1905 in a commercial clear-cutting operation or a heavy high-grading. As a result, by 1958 the tract contained about one-half of its volume in held-over trees, many of which were partially or wholly defective. The remainder of the tract was composed of second-growth small sawtimber and poletimber. The stands on this tract were well stocked with good growing-stock trees. A 10-percent inventory showed 8,723 board feet per acre in merchantable trees over 11.0 inches d.b.h.[3] Total merchantable volume for the tract was approximately 5.2 million board feet.

The sawtimber component of the tract had the following species composition: northern red oak, 40 percent; yellow-poplar and cucumbertree, 22 percent; white oak, 7 percent; sugar maple, 6 percent; red maple, 6 percent; basswood, 4 percent; white ash, 3 percent; black cherry, 2 percent; and other, generally low-valued species, 10 percent.

Seventy-three percent of the merchantable sawtimber stand was in factory-lumber logs while 27 percent of the logs were below factory-log grade. The distribution by log grade was as follows:

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[3] International ¼-inch kerf rule to an 8-inch top d.i.b.

log grade one, 27 percent; log grade two, 13 percent; log grade three, 33 percent; and below factory grade, 27 percent.

This timber tract has a better than average site quality, ranging from 60 to 90 feet at 50 years for oak, and having a weighted average oak site index of 74. The tract is located in steep mountain terrain with slopes averaging 40 percent, but ranging from flat ridge tops to slopes as steep as 70 percent.

The Trial Management Program

An early step in development planning is to prepare a trial management program for the development period. Timber tracts like the sample tract can be managed by either an even-aged or an uneven-aged system. Under the former system such desirable intolerants as yellow-poplar and black cherry would be favored while the latter system would favor the tolerant, aggressive (and also desirable) sugar maple.

For the long-range management system it was decided to use a compromise: a patch cutting or group-selection system with a 10-year cutting cycle. Past experience indicated that this system provides good control over species composition and grade distribution, while providing for adequate regeneration of the more intolerant and valuable timber species. It was further decided to manage this tract for the production of sawtimber.

Because this timber tract initially had a large volume in old residuals—left over from the 1905 harvest—that were mostly financially overmature and in many cases defective, the first task was to apply a conditioning cut designed both to harvest old growth and to provide improved growing condition for subsequent production. The next harvest operation was planned to follow the conditioning cut in 15 years, with subsequent harvests at 10-year intervals.

This management program is aimed at an equilibrium condition where residual volume is maintained at 7,000 board feet per acre; growth at about 300 board feet per acre per year, and species and grade distributions such that the average stumpage value for harvest volume approaches $25 per thousand board feet at 1964 prices.

The basis for computing all costs and returns was local going rates in 1964.

The Road System

The managers of this Experimental Forest do their own logging on this tract, using tree-length skidding to log landings where trees are bucked and loaded on trucks. This system, using a tractor and arch, is well adapted to the steep mountain terrain. Tree-length logs are winched to skidroads in this operation, and the tractor and arch does not leave the skidroads. Winching distance is held to 200 to 300 feet in most cases. The equipment consists of an International TD-9 crawler tractor and a rubber-tired sulky arch. All felling and bucking is done with power saws. Skidding distances are held to ½ mile if at all possible, and ¼ mile is the average distance aimed at.

This sort of a logging operation, then, calls for a year-round truckroad and dry weather truckroad spurs to allow access to within ½ mile of any point in the tract, as well as skidroads at about 600-foot intervals. Three miles of truckroad were constructed at a cost of $2,000 per mile.[4] Skidroads and log landings cost another $3,700 for a total initial cost of $9,700 for the road system. Of this total cost some $2,400 is depreciated during each harvest operation. This depreciation consists of: (1) the cost of truckroad spurs and skidroads that will be abandoned or relocated at the next harvest, (2) the cost of maintaining the main truckroad during harvest, and (3) the cost of after-harvest care for skidroads. The net continuing investment in the road system, then, is about $7,300, and a further cost of $2,400 at each harvest operation. In addition there is a general overhead expense of $100 per year annual maintenance cost for the truckroads, to allow access between harvest operations.

The Conditioning Cut

The first harvest operation was carried out on this tract in 1958. About 2.7 thousand board feet per acre was removed in this cut-

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[4] The roads were actually constructed years before, and the cost figures are approximations that experience has shown to be the amount needed for building logging truckroads in this area.

Table 2. — *The conditioning cut in the trial development program, 1958*

Income or cost item	Actual value per thousand board feet
Lumber value	$ 76.45
Loading and hauling costs	7.00
Milling cost	30.00
Allowance for profit and risk (11%)	8.41
Gross income	$ 31.04
Marking cost	$ 1.00
Felling, limbing, and topping cost	3.98
Skidding cost	9.20
Bucking cost	.81
Grading and scaling cost	1.33
Road system depreciation and maintenance cost	1.48
Logging supervision cost	.68
Forester's supervision cost	.05
Net income	$ 12.51

ting, made up of 13 or 14 trees per acre averaging 18 inches d.b.h. In addition about three culls per acre were marked for deadening. The average value per thousand board feet for the harvested material was about $12, and total income from the harvest exceeded $20,000. Of this amount $7,300 represented the residual value of the road system; some $500 or $600 was spent on cull-tree deadening, and over $12,000 remained as cash income.

Some pulpwood, charcoal wood, post, and rail stumpage was sold to local operators, producing a net income of a little over $300. These small-product sales took place over approximately only 120 acres of the 600-acre tract, partly because small-products have positive stumpage values only when there is a truckroad within 150 or 200 yards.

The residual stand averaged 6.0 thousand board feet per acre with an average stumpage value of about $9.28 per thousand board feet. This conditioning harvest operation is detailed in table 2.

Subsequent Harvests

The next harvest[5] is scheduled for 1973, 15 years after the conditioning cut, when the tract should have an average volume of about 10.5 thousand board feet per acre, and an average value of about $14 per thousand board feet. The harvest will take about 3.5 thousand board feet per acre with an average value in excess of $17 per thousand board feet, for a total net income of about $37,000. Of this total about $400 will be spent on deadening cull trees and the remainder will be available as cash income. No additions to the basic road system are contemplated. The residual stand will have about 7.0 thousand board feet per acre with an average value above $12 per thousand board feet.

The third harvest is scheduled for 1983 and will be similar to the second except that average value of the stumpage will increase because of continuing improvement in species composition, tree size, and grade distribution. Costs for cull-tree removal will have

Table 3. — *The second harvest in the trial development program, 1973*

Income or cost item	Projected value per thousand board feet
Lumber value	$ 82.71
Loading and hauling cost	7.00
Milling cost	30.00
Allowance for profit and risk (11%)	10.09
Gross income	$ 35.62
Marking cost	$ 1.00
Felling, limbing, and topping cost	3.98
Skidding cost	9.20
Bucking cost	.81
Grading and scaling cost	1.33
Road system depreciation and maintenance cost	1.14
Logging supervision cost	.68
Forester's supervision cost	.05
Net income	$ 17.43

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[5] Growth rate and quality change information were available from the record of uneven-aged management compartments on the Fernow Experimental Forest and were used to arrive at future values on the study area.

Table 4. — *The final harvest in the trial development program, 1983*

Income or cost item	Projected value per thousand board feet
Lumber value	$ 88.76
Loading and hauling cost	7.00
Milling cost	30.00
Allowance for profit and risk (11%)	10.78
Gross income	$ 40.98
Marking cost	$ 1.00
Felling, limbing, and topping cost	3.98
Skidding cost	9.20
Bucking cost	.81
Grading and scaling cost	1.33
Road system depreciation and maintenance cost	1.33
Logging supervision cost	.68
Forester's supervision cost	.05
Net income	$ 22.60

leveled off at about $300. These harvest operations are detailed in tables 3 and 4. The assumption is that equilibrium in harvested values will be reached at the third harvest—unless management objectives change.

No changes in costs—except for cull killing and road systems—are provided for with succeeding cuttings. In practice there probably would be cost changes and the trend would perhaps be to lower costs in the latter cuttings.

Evaluating the Trial Program

The basic facts of the trial program are summarized in table 5. This table includes an estimate of total tract value at various points in time. The initial value for the tract is based on an average of five independent appraisals made of the tract by two consulting foresters, an industrial forester, and a tax assessor, and one resulting from the application of Forest Service appraisal procedures. The various appraisals of the growing stock ranged from $35,000 to $98,000, indicating the diversity of appraisal

Table 5.—*Summary of the trial development program, 1958-83*

Year and item	Per-acre volume	Value per thousand board feet	Tract land value	Tract growing-stock value	Road-system value	Total tract value	Net income	Reinvested		Cash income
								In road	In cull treatment	
	Thousand board feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1958 Purchase inventory	8.7	10.34	3,600	54.000	—	57,600	—	—	—	—
Conditioning cut	2.7	12.50	—	—	—	—	20,580	7,300	567	12,713
Residual inventory	6.0	9.28	3,600	33,420	7,300	44,320	—	—	—	—
1973 Pre-cut inventory	10.5	14.02	3,600	88,326	7,300	99,226	—	—	—	—
Harvest	3.5	17.43	—	—	—	—	36,917	—	420	36,497
Residual inventory	7.0	12.24	3,600	51,409	7,300	62,309	—	—	—	—
1983 Pre-cut inventory	10.0	16.00	3,600	96,000	7,300	106,900	—	—	—	—
Harvest	3.0	22.60	—	—	—	—	40,724	—	270	40,724
Residual inventory	7.0	13.10	3,600	55,006	7,300	65,906	—	—	—	—

methods and viewpoints taken by the various appraisers. The bare land was valued uniformly at $6.00 per acre.

The median appraised value of the property in 1958 was $57,600. The 1958 cutting provided a net cash income of $12,713, so that the net investment in the property after the conditioning cut was $44,887. A net cash income of $36,497 is expected in 1973, and a further income of $40,724 is anticipated in 1983. After the 1983 cutting, investments in the road system and improvement in the quality of growing stock will have increased the value of the property to $65,906. There is an administrative cost for the property of about $600 per year. This is made up of an annual tax bill of about $325, the $100 road-maintenance cost, and other miscellaneous overhead and administrative expenses.

If this tract had actually been purchased at $57,600, and the expected future expenses and income occurred, then the investment would return 4½ percent before income taxes during the 25 year development period. Thereafter the investment return would be about 4.2 percent. If a potential purchaser of the tract felt he needed an 8-percent return during the development period he would not have purchased the tract unless it had been available for $33,384 or less.

Adjusting the Trial Program

A 4- or 4½-percent return on investment is a respectable return in the timber-growing business, but it may be possible to adjust the trial management program to improve the financial return. For example, the trial program may specify a level of stocking well beyond the optimum. Residual stocking is held to 7.0 thousand board feet per acre in the trial program. It is possible that this could be reduced to 6.0 thousand board feet without sacrificing much in the way of growth or average value.

If the conditioning cut were increased 1.0 thousand feet per acre, its cash income might well increase to $20,213, and the net investment in the tract after the cutting would be $37,387 rather than $44,887 of the trial program. It is assumed that incomes from the subsequent harvests would remain about the same and property value at the end of the period would be $58,060 rather than $65,726. Under these conditions the average rate of return for the investment during the development period would increase to about 5.1 percent, and to about 4.7 percent afterward. This is a substantial improvement, and it would certainly be worth while to investigate the effect of stocking level on returns more thoroughly. Also, the revised stocking level allows the prospective purchaser who wants an 8-percent return to offer as much as $46,137, an increase of almost $13,000. This shows how important it is to plan tract development as a prelude to establishing tract value.

Almost any owner would be in favor of an adjustment like the one in stocking levels. Another way of improving returns, however, calls for added investment during the development period to improve returns subsequently. Cull-tree removal has been the only out-of-pocket investment made in timber culture. Another investment possibility is to do pre-commercial release of potential crop trees in the group-selection openings. This practice can increase growth, give further control over species composition, and improve grade yields. However, these effects will probably not be felt until after the development period when released trees are harvested.

A PLANNING OUTLINE

The following brief outline may be helpful in planning for timber-tract development.

Step 1: Inventory.—This initial phase in planning requires the mapping and inventory of the timber tract, the assembling of biological growth and yield information, and an assessment of timber markets and ownership objectives and restraints. The markets for timber products, both current and long-run, have an important influence on development planning; and current and prospective prices for timber products should be established with care. The manager must be aware of the owner's management objectives for the tract. Such considerations as what income is required from the property at which intervals, what minimum rate of return is acceptable, and under what conditions the owner might wish to disinvest, are all necessary planning data. At the end of this first step the planner should have at hand most of the information about the timber tract, timber markets, and owner objectives that he needs to undertake preliminary planning.

Step 2: Trial development program.—The second step in development planning is to set up a trial management program for the development period. The first task is to prescribe a stable growing-stock condition toward which to aim, and a complementary set of physical improvements. The target growing-stock condition must be attainable within the development period and be geared to prospective markets. The kind of growing stock also ought to be set up with regard to what is justifiable from the economist's point of view as well. Physical improvements in the property should be limited to what is necessary to implement the management program required to secure and maintain the target growing-stock condition. When the trial development program has been specified, it is to be evaluated by determining all the costs and income it will occasion and by computing the rate of return these costs and incomes indicate.

Step 3: Adjustment.—The final step in development planning is to test marginal changes in various aspects of the trial program for their effect on returns. The planner can adjust both the target growing-stock and physical-improvement goals and the time needed to obtain these goals. In some cases the trial program will require more investment than the owner is willing to make, return smaller incomes than he desires, or provide an unacceptably low return on his investment. These deficiencies will point the way to needed adjustments. In other cases the trial program may be acceptable to the owner, but the planner should still try some of the more obvious changes that might be made to see whether an improved return can be had. Contemplated changes are traced through the development program; their effect on growth and yield and on costs and incomes is estimated, and the revised program is re-evaluated to determine the net effect.

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FORESTRY ACCOMPLISHMENTS

in southeastern Ohio under the U.S. Agricultural Conservation Program, 1957-64

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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FORESTRY ACCOMPLISHMENTS

in southeastern Ohio under the U.S. Agricultural Conservation Program, 1957-64

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THE HILL COUNTRY

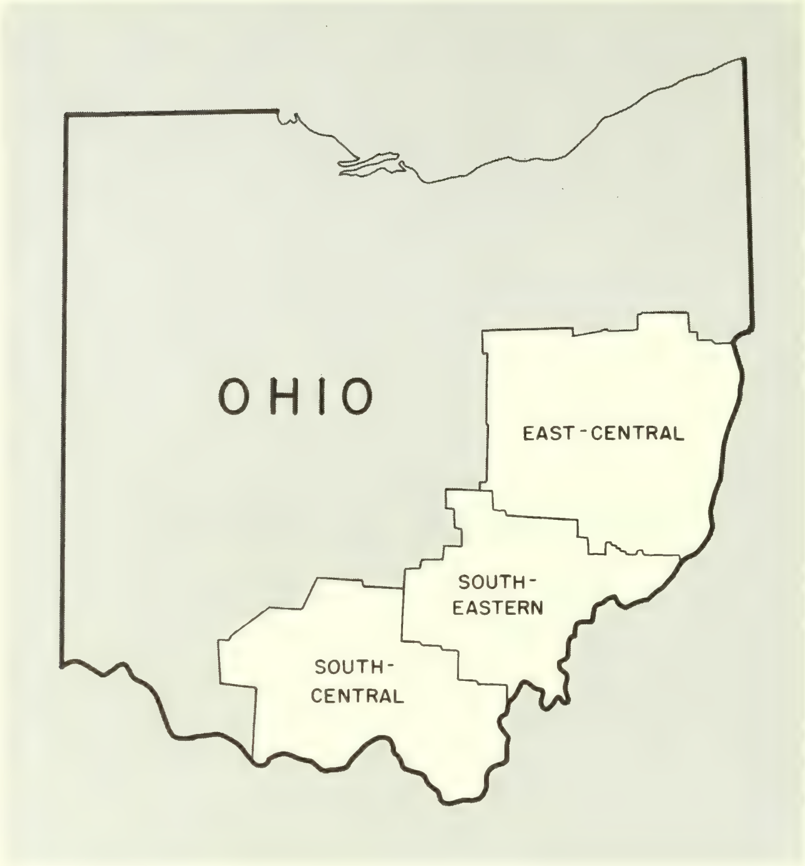
THE HILL COUNTRY occupies the southeastern part of Ohio (fig. 1). Here more than one-third of the land area is covered by forests that are privately owned. The extent of this forest area (3.2 million acres), and the forest products from it have a considerable impact on the economic well-being of this region.

Estimates of potential timber growth in the region range from 100 to 300 board feet per acre per year. If the most conservative estimate of 100 board feet per acre is used, the privately owned forest land of this region could provide approximately 320 million board feet annually.

Many markets for this timber already exist. In almost all these markets, quality is stressed. Veneer- and cooperage-quality timber bring premium prices, and good-quality sawtimber finds a ready market. In addition, new wood-using industries are constantly seeking locations that can provide an assured source of quality timber.

Estimates of the growth-cut relationship in the Hill Country indicate that at present less than one-half of the annual growth is being cut. Thus there appears to be no dearth of low-quality timber.

Figure 1.—The Hill Country of Ohio and its subregions.



A PROBLEM & AN OPPORTUNITY

A basic problem in the Hill Country of Ohio is to up-grade the quality of timber and get trees or other cover back on abandoned land. This is admittedly a long-term venture; but the opportunity to establish a stable wood-using industry that will benefit the landowner, the logger, and the region as a whole, make the task worthwhile.

One answer to this problem lies in the forestry practices portion of the U.S. Agricultural Conservation Program (ACP), which, in conjunction with the forestry service activities of the

Ohio Department of Natural Resources, has provided since 1957 for financial assistance and technical advice in such practices as timber-stand improvement, tree pruning, site preparation for tree planting, fencing of woodlots, and tree planting. The financial assistance is considerable, covering in some cases 80 percent of the cost of the practice. The technical assistance is free for the asking, and this combination of financial assistance and technical advice is available to any forest landowner who is conscientiously interested in returning his forest land to a productive state.

In view of the fact that much of the Hill Country is an area of low income and chronic unemployment and has been designated a part of the Appalachian Region, an analysis of the forestry practices of the ACP in this area is timely. The role of the ACP in economic development and in the long-term task of up-grading the forest resource of the Hill Country should be clearly defined and its rate of accomplishment of the overall task noted. The mere existence of forestry practices in the ACP is no assurance that the problem is being adequately attacked. Further, this analysis is admittedly but one facet of the myriad information that is necessary to formulate an economic analysis of the forest resource.[1]

THE PROGRAM

The forestry program of the ACP is carried out under practices designated as A-7 and B-10.[2] The A-7 practice provides for cost-sharing assistance in tree planting; the B-10 practice provides for timber-stand improvement, site preparation, pruning, and fencing.

The accomplishments of the program vary annually by county and are determined by the total appropriation for the program, the guidelines established by the national and state development groups, the overall amount of money made available for all conservation practices within a county, and the general outlook of the elected county committee. This committee, which is made up of local farmers, in the final analysis determines the proportions of

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[1] A brief analysis for each of the three subregions of the Hill Country is presented in the Appendix.

[2] Descriptions of the A-7 and B-10 practices are presented in the Appendix.

Table 1.—*Accomplishments under forestry practices of the Agriculture Conservation Program in the Hill Country of Ohio, 1957-64*

Forestry practice		1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	acres	1,484	2,093	2,383	2,841	2,106	4,113	3,518	2,559	21,097
Site preparation	acres	3	13	—	25	69	22	15	—	147
Pruning	acres	66	206	53	421	103	104	135	107	1,195
Fencing	rods	7,873	6,122	12,802	11,262	11,850	13,450	7,896	8,065	79,320
All B-10 practices	acres	1,553	2,312	2,436	3,287	2,278	4,239	3,668	2,666	22,439
	rods	7,873	6,122	12,802	11,262	11,850	13,450	7,896	8,065	79,320
A-7 practice	acres	1,878	1,619	1,968	2,031	1,938	1,834	1,892	1,442	14,602
Total	acres	3,431	3,931	4,404	5,318	4,216	6,073	5,560	4,108	37,041
	rods	7,873	6,122	12,802	11,262	11,850	13,450	7,896	8,065	79,320

Table 2.—*Total ACP assistance for forestry practices in the Hill Country of Ohio, 1957-64*

Foresty practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	$20,802	$30,241	$ 33,525	$ 34,116	$ 30,888	$ 57,728	$ 51,477	$38,948	$297,725
Site preparation	72	92	—	64	1,451	228	168	—	2,075
Pruning	1,532	3,176	972	1,296	2,381	3,056	3,556	2,645	18,614
Fencing	7,870	6,390	18,947	16,719	14,975	19,935	11,724	12,101	108,661
All B-10 practices	$30,276	$39,899	$ 53,444	$ 52,195	$ 49,695	$ 80,947	$ 66,925	$53,694	$427,075
A-7 practice	51,314	54,317	57,302	62,271	67,777	65,806	63,236	38,183	460,206
Total	$81,590	$94,216	$110,746	$114,466	$117,472	$146,753	$130,161	$91,877	$887,281

the available appropriations that are to be applied to the various practices.

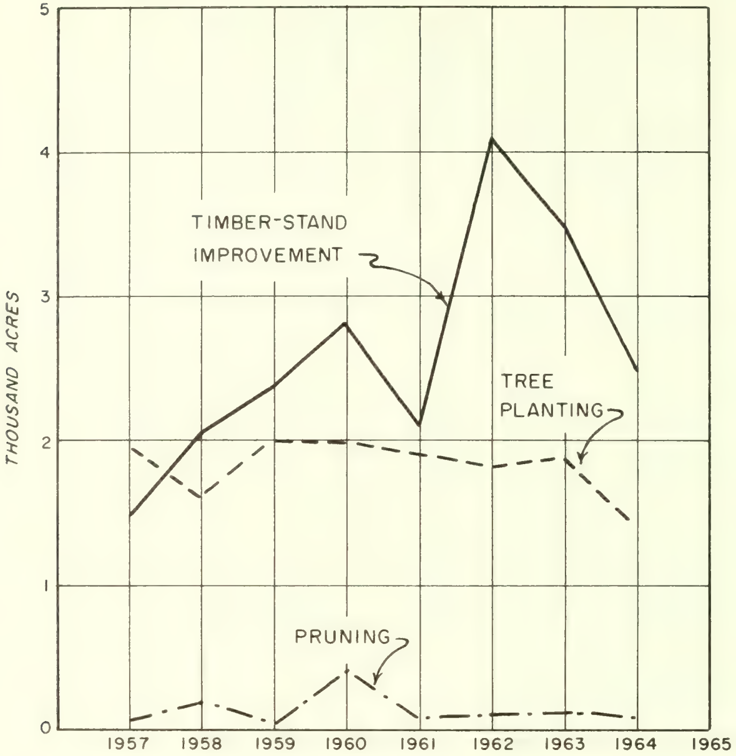
ACREAGE ACCOMPLISHMENTS

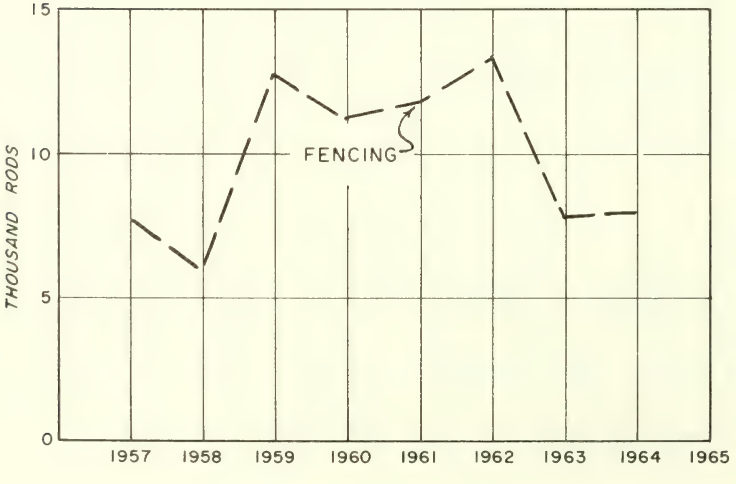
In general, forestry accomplishments under the ACP have increased during the 8-year period 1957-64. Forest improvements were made on a total of 37,041 acres, about 4,630 acres annually (table 1). Approximately 57 percent of this total acreage underwent timber-stand improvement; 39 percent tree planting; 3 percent pruning; and less than ½ percent site preparation. In addition to the acreage improved, more than 79,000 rods of fencing were erected to protect the forest from grazing livestock.

Distinct trends are evident in these accomplishments. Since 1957, the overall trend has been an increase in tree planting and cultural operations. The peak of this increase was reached in 1962 when a total of some 6,000 acres were improved and more than 13,000 rods of protective fencing were erected. However, since 1962 the trend has been downward and the total tree-planting and cultural operations have decreased by some 500 acres and 1,500 acres in 1963 and 1964, respectively.

Though a knowledge of overall trends is of considerable importance, a more concise portrayal of the effect of ACP is revealed in an analysis of the individual cultural operations (fig. 2). In timber-stand improvement work, which has been accomplished on an average of some 2,640 acres annually over the 8-year period, the annual accomplishment has been rather erratic. In contrast, the annual achievements of tree-planting and pruning operations, which average some 1,850 acres and 149 acres, respectively, have remained relatively stable. Fencing, the single feature of the forestry practices whose accomplishment is measured in lineal terms (an average annual rate of some 9,900 rods), exhibited the most erratic record. The greatest increase in fencing occurred in 1959, when a gain of 109 percent over the previous year was made; the greatest lag in fencing occurred in 1963, when the annual achievement diminished by some 41 percent over that of the previous year.

Figure 2.—On-the-ground accomplishments of the forestry practices of the Agricultural Conservation Program in the Hill Country of Ohio, 1957-64.





The erratic annual accomplishments of the various forestry practices underscore the need for vigilance in what must necessarily be a long campaign to return the forests to a more productive state. Thus, another and probably most important question arises: What are the needs of the forests of this area, and to what extent is the ACP meeting these needs?

An answer to the first part of this question has already been recorded in the Ohio Soil and Water Conservation Needs Inventory of 1961, which showed that by 1975 some 2.8 million acres in the Hill Country of Ohio will need conservation treatment (see Appendix III).[3] According to this report, approximately 430,000 acres need tree planting, 1.4 million acres need timber-stand improvement, and about 1 million acres need to be fenced from animals. Commendable as the 8-year achievement of the forestry practices of the ACP may appear, the overall goal set by the Conservation Needs Inventory has not been reached. The 22,000 acres of timber-stand improvement represent only 1.6 percent of the estimated need, and the 14,600 acres of tree planting about 3.4 percent of the need. A comparison of accomplishment and need for fencing is not calculable.

On an average basis, the annual timber-culture achievement on some 2,800 acres represents 0.2 percent of the estimated need, and the annual tree-planting rate of 1,825 acres represents 0.4 percent of the need. Assuming that these annual rates are maintained through 1975, accomplishments under ACP forestry practices will account for only 3.7 percent of the timber-stand-improvement work and 7.6 percent of the tree planting that was recommended in the Conservation Needs Inventory.

DOLLAR COSTS

A consideration of the dollar amounts involved will provide another measure necessary for an assessment of the costs involved in fulfilling even a small portion of the conservation needs. Total cost-sharing assistance provided by the ACP for the 8-year period amounted to $887,000, of which 52 percent was for tree planting under the A-7 practice, 34 percent was for timber-stand improvement, 12 percent for fencing, and 2 percent for pruning under the B-10 practice (table 2). Site preparation accounted for less than ½ percent.

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[3] Reeser, Robert M. OHIO SOIL AND WATER CONSERVATION NEEDS INVENTORY. Ohio Agr. Ext. Serv., Columbus, Ohio. 1961.

Cost-sharing assistance for tree planting is the greatest expenditure for forestry practices in the Hill Country. It averaged some $57,500 annually, or approximately $31.50 per acre. For the most part, these expenditures have been remarkably stable (table 3 and fig. 3). Since 1962, cost-sharing assistance for tree planting has

Figure 3.—Dollar cost-sharing assistance for tree planting under the A-7 practice of the Agricultural Conservation Program in the Hill Country of Ohio, 1957-64.

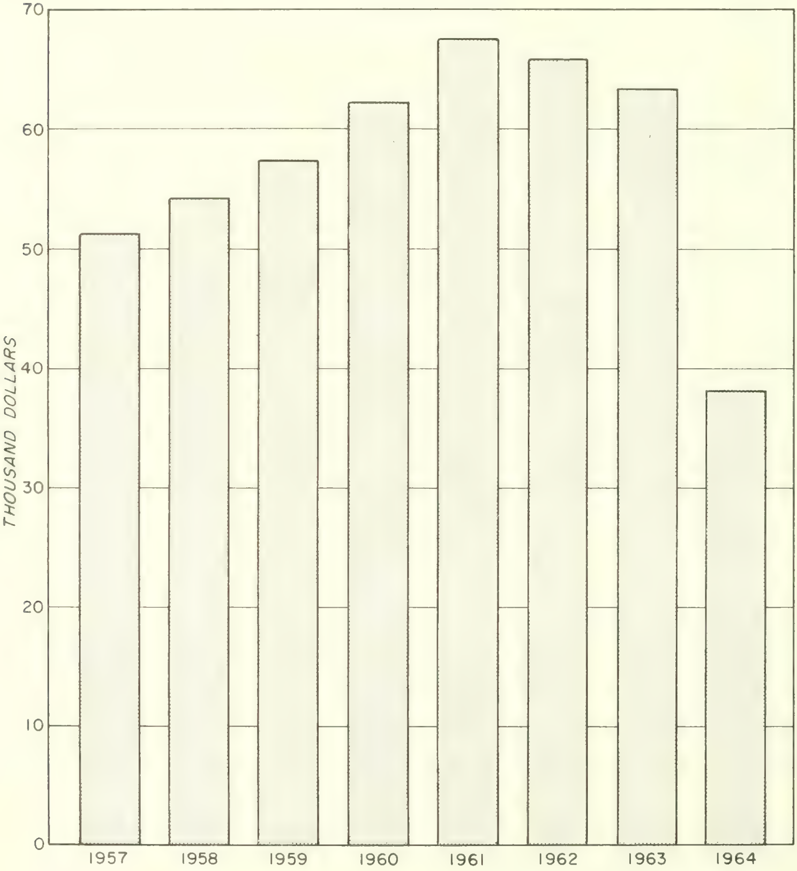


Table 3.—*Annual rate of change of cost-sharing assistance for forestry practices, in percent*

Year	Tree planting	Timber-stand improvement	Fencing	Pruning & site preparation	All forestry practices
1957	—	—	—	—	—
1958	+ 5.9	+45.4	— 18.8	+103.7	+15.5
1959	+ 5.5	+10.9	+196.8	— 70.3	+17.5
1960	+ 8.7	+ 1.2	— 11.8	+ 39.9	+ 3.4
1961	+ 8.8	— 9.5	— 10.4	+181.8	+ 2.6
1962	— 2.9	+86.9	+ 33.1	— 14.3	+24.9
1963	— 3.9	—10.8	— 41.2	+ 13.4	—11.3
1964	—39.6	—24.3	+ 3.2	— 29.0	—29.4

decreased, and there has been a corresponding reduction in acreage planted.

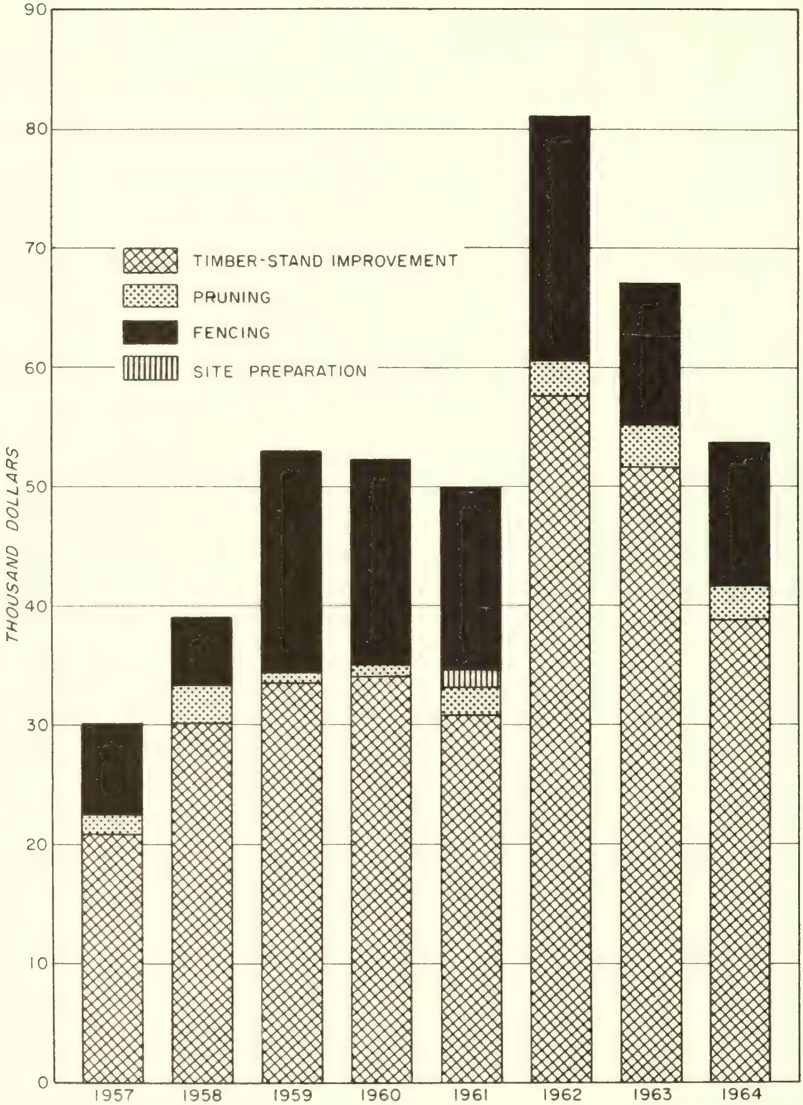
Assistance for timber-stand improvement, the second largest expenditure for forestry practices, averaged some $37,200 annually, or approximately $14.10 per acre. However, these expenditures have been very erratic over the 8-year period, registering annual rates of change in dollar costs as high as 87 percent (table 3 and fig. 4).

Fencing accounted for the greatest percentage of variation in annual expenditures, ranging between a low of $6,400 in 1958 and a high cost of $19,900 in 1962 (table 3). The average annual cost-sharing assistance amounted to $13,600, or about $1.30 per rod.

Pruning and site preparation were relatively minor in expenditures for forestry practices in the Hill Country, averaging some $2,600 annually. This annual cost-sharing assistance also fluctuated over an annual rate of change of as much as 182 percent (table 3). Average per-acre costs for pruning and site preparation amounted to $15.58 and $14.12, respectively.

Total annual cost-sharing assistance for all practices did not vary as widely as assistance for individual practices (table 3). Annual average assistance amounted to $110,910, ranging from a low of $81,590 in 1957 to a high of $146,750 in 1962.

Figure 4.—Dollar cost-sharing assistance for timber culture operations under the B-10 practice in the Hill Country of Ohio, 1957-64.



This review of dollar costs illustrates that, although total cost-sharing assistance over the 8-year period was fairly stable, this stability was lacking within the individual practices. To a great extent, this signifies a need for establishing annual achievement goals for each of the individual cultural practices and, more specifically, goals that are predicated more closely on region-wide needs than on the diversity resulting from participation.

PARTICIPATION

The accomplishments of the ACP forestry practices can be measured in yet another manner: on the basis of owner participation. On the average, approximately 600 owners, or only 1.7 percent of the forest-land owners of the Hill Country, participated annually in the forestry practices of the ACP (table 4). Some 65 percent of these participants engaged in tree planting while 35 percent undertook timber-culture practices.

Although tree planting accounted for the greatest percentage of participation, the trend exhibited over the 8-year period was definitely downward (fig. 5). It waned from a high of 535 participants in 1957 to a low of 297 in 1964. This reduction in participation, however, was more or less offset by the increase in acreage planted per participant; and, as a result the annual acreage planted has not reflected the downward trend in participation.

In the B-10 practices, the trend in participation was generally upward until 1962; then the course was reversed. Participation in this practice fluctuated from a low of 133 participants in 1957 to a high of 309 in 1962. Approximately 1,700 individuals participated in one or more activities of the B-10 practice over the 8-year period. Some 58 percent of the participants were involved in timber-stand improvement, 31 percent in fencing, and 10 percent in pruning. Only 1 percent undertook site preparation.

One other comparison should be made to place the forestry practices of the ACP in proper perspective: a comparison of the forestry practices with the total gross outlay for ACP assistance (table 5). For the most recent 4-year period, 1961-64, an average of only 6.4 percent of the total gross assistance was applied to forestry practices. It is important to note that in the last year of record (1964) this proportion was reduced to 5.1 percent.

Table 4.—*Number of participants in forestry practices of ACP in the Hill Country of Ohio, 1957-64*

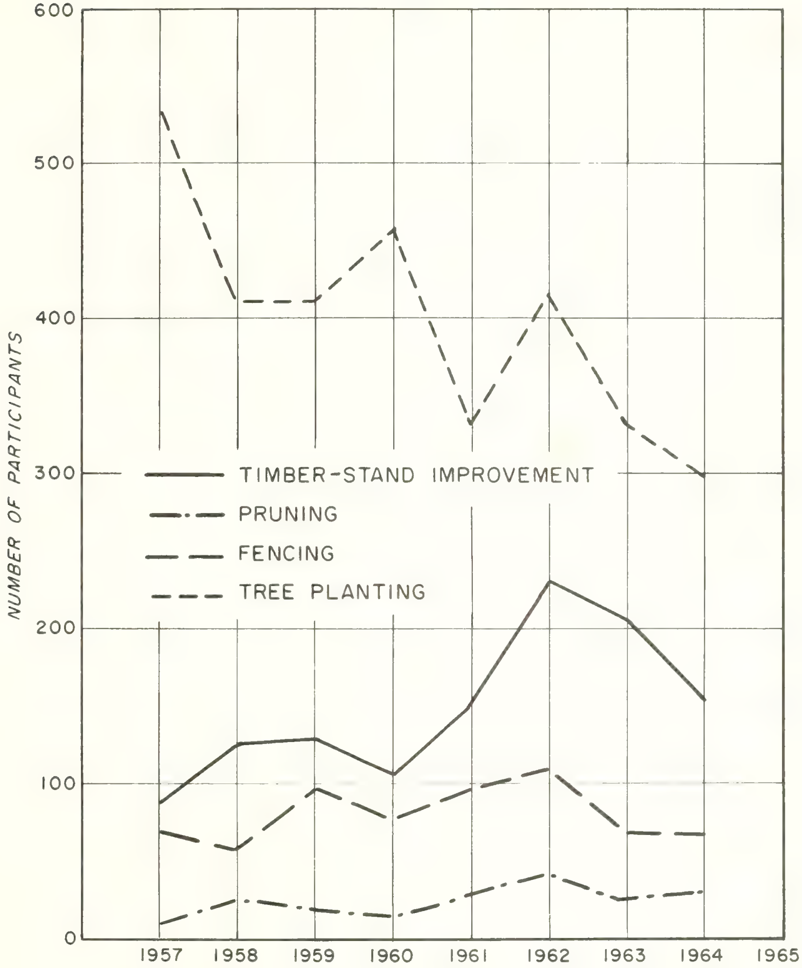
Forestry practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	83	125	128	105	151	231	205	151	1,179
Site preparation	1	2	—	2	3	4	13	—	25
Pruning	11	25	18	14	29	42	25	31	195
Fencing	69	58	96	77	97	110	69	68	644
All B-10 practices[1]	133	170	199	170	229	309	279	223	1,712
A-7 practice	535	410	411	456	333	416	331	297	3,189
Total	668	580	610	626	562	725	610	520	4,901

[1] Non-additive because of owners participating in more than one practice.

Table 5.—*Comparison of total gross Agricultural Conservation Program assistance and assistance for ACP forestry practices in the Hill Country of Ohio, 1961-64*

Forestry practice	1961	1962	1963	1964	Total
B-10 forestry practices	$ 49,695	$ 80,947	$ 66,925	$ 53,694	$ 251,261
A-7 forestry practice	67,777	65,806	63,236	38,183	235,002
Total	$ 117,472	$ 146,753	$ 130,161	$ 91,877	$ 486,263
Total gross ACP assistance	$1,882,547	$2,048,379	$1,863,109	$1,795,086	$7,589,121
Percent of forestry practice in total gross ACP payments	6.2	7.2	7.0	5.1	6.4

Figure 5.—Participation in forestry practices of the Agricultural Conservation Program in the Hill Country of Ohio, 1957-64.



CONCLUSION

The purpose of this article has been to define the gap that exists between the accomplishments of the Agricultural Conservation Program and the estimated need for accomplishment by 1975 as presented by the Conservation Needs Inventory. Of necessity it has been descriptive rather than definitive. However, it presents a detailed insight into the costs and accomplishments of and participation in the program, which till now has not been available.

It should be stated that the ACP, by itself, was never intended to accomplish the entire goal of assisting woodland owners in renewing and improving their timber stands. The anticipated accomplishment of approximately 4 percent of the estimated timber-culture work and 8 percent of the estimated tree planting needed by 1975 must be supplemented by other private and public efforts if the goals are to be reached.

Accomplishments of individual forestry practices have been rather erratic, showing the need for close stewardship of the program if it is to achieve its goals. A desirable degree of stability might be expected in the program if annual goals for the individual timber-culture practices were established on a regional or even a county basis. Furthermore, depending on the kind and extent of the land, there may be sufficient justification for reassessing the emphasis—or lack of emphasis—on forestry practices in the ACP.

■

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I

A SUBREGIONAL APPROACH

The preceding discussion presented quantitative data for the Hill Country of Ohio as a whole. However, even within this 26-county area there are differences that merit consideration from a subregional approach. The quality and extent of open land, which determines in part the need for tree planting; and the quality, age, and extent of the forest, which determines participation in such activities as timber-stand improvement and pruning, are but a few of the items that must be considered in developing a subregional approach.

The benefits that accrue from this more intensive approach warrant the effort. Information derived from such an analysis focuses attention on the requirements of the forest resource of the subregions and the extent to which these requirements are being met. A discussion of the subregions emphasizes changes that occur within the program in a particular subregion.

In this respect, the Hill Country of Ohio can be divided into three distinct subregions: East-Central, Southeastern, and South-Central (fig. 1).

East-Central Subregion

Although only 29 percent of the land is forested, the estimated conservation needs of the East-Central Subregion are the greatest in the Hill Country. The Conservation Needs Inventory indicates that some 234,000 acres require tree planting, about 631,000 acres need timber-stand improvement, and more than 434,000 acres need fencing. These conservation needs represent about 54 per cent of the tree planting, 46 percent of the timber-stand-improvement work, and 42 percent of the fencing that is recommended in the Hill Country.

Approximately 59 percent of the assistance money appropriated for forestry practices in the Hill Country from 1957 to 1964 was used in the East-Central Subregion. Within the subregion, the conservation improvement effort is almost equally divided among tree planting and cultural operations (tables 6 and 7).

Participation in the forestry practices here is the greatest for any of the subregions, accounting for some 3,000 participants over the 8-year period, or 62 percent of the total Hill Country participation (table 8.)

The relatively concerted effort on forestry practices in this subregion is further demonstrated by the fact that an annual average of 8.3 percent of the total gross ACP cost-sharing assistance for the East-Central Subregion was applied to forestry practices (table 9). This was the highest percentage appropriated for forestry practices for any of the subregions of the Hill Country.

If this effort continues and the average annual rates of achievement are maintained (1,304 acres of timber-stand improvement and 1,140 acres of tree planting), the accomplishments of the forestry practices of the ACP in the East-Central Subregion of the Hill Country from 1958 to 1975 will account for 3.7 percent of the needed timber-stand-improvement work and 8.8 percent of the required tree planting.

Southeastern Subregion

Approximately one-half of the land area of this subregion is forested; and conservation needs are estimated at 119,000 acres of tree planting, 546,000 acres of timber-stand improvement, and 339,000 acres of fencing. This represents approximately 28 percent of the tree planting, 40 percent of the timber stand improvement, and 33 percent of the fencing that is required in the entire Hill Country according to the Conservation Needs Inventory.

Approximately $29,000 is expended annually for forestry practices, which represents 26 percent of such cost-sharing assistance in the Hill Country (tables 10 and 11). Tree planting, which is the major activity, accounts for about 62 percent of the total assistance; and cultural practices account for the remaining 38 percent.

Only 26 percent of the participants in ACP forestry practices are located in this subregion (table 12). Almost 70 percent of them are engaged in tree planting and 30 percent in cultural practices. An average of 8.0 percent of the total gross ACP cost-sharing assistance is applied for forestry practices (table 13).

If tree planting and timber-stand improvement continue at the same average annual rate of 588 acres and 535 acres, respectively, the accomplishments of ACP since 1958 will account for 8.9 percent of the estimated tree-planting needs and 1.8 percent of the estimated timber-culture operations needed by 1975 in the Southeastern Subregion.

South-Central Subregion

Despite the fact that this subregion contains more forest acreage than any of the other subregions, the estimated conservation needs are smaller. Approximately 77,000 acres require tree planting, 195,000 acres require

Table 6.—*Total ACP assistance for forestry practices in east-central Ohio, 1957-64*

Forestry practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	$13,192	$15,462	$16,752	$20,967	$19,823	$31,272	$23,425	$19,354	$160,247
Site preparation	72	72	—	64	197	210	45	—	660
Pruning	911	2,611	879	1,145	1,824	2,503	3,201	2,109	15,183
Fencing	5,302	3,604	10,863	7,292	7,537	13,144	5,835	5,387	58,964
All B-10 practices	$19,477	$21,749	$28,494	$29,468	$29,381	$47,129	$32,506	$26,850	$235,054
A-7 practice	35,923	38,630	40,847	41,457	45,136	33,704	37,435	18,949	292,081
Total	$55,400	$60,379	$69,341	$70,925	$74,517	$80,833	$69,941	$45,799	$527,135

Table 7.—*Accomplishments under forestry practices of Agricultural Conservation Program in east-central Ohio, 1957-64*

Forestry practice		1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	acres	849	965	884	1,345	1,024	1,819	1,286	1,160	9,332
Site preparation	acres	3	3	—	25	14	21	3	—	69
Pruning	acres	43	160	48	412	84	88	112	83	1,030
Fencing	rods	5,302	3,604	7,290	4,936	5,987	8,779	3,890	3,591	43,379
All B-10 practices	acres	895	1,128	932	1,782	1,122	1,928	1,401	1,243	10,431
	rods	5,302	3,604	7,290	4,936	5,987	8,779	3,890	3,591	43,379
A-7 practice	acres	1,287	1,114	1,390	1,233	1,211	941	1,182	757	9,115
Total	acres	2,182	2,242	2,322	3,015	2,333	2,869	2,583	2,000	19,546
	rods	5,302	3,604	7,290	4,936	5,987	8,779	3,890	3,591	43,379

Table 8.—*Participation in forestry practices of ACP in east-central Ohio by number of farms, 1957-64*

Forestry practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	55	70	64	63	99	133	96	74	654
Site preparation	1	1	—	2	2	3	1	—	10
Pruning	9	20	16	12	24	37	22	25	165
Fencing	48	36	58	35	49	69	39	31	365
All B-10 practices[1]	89	97	109	95	139	186	140	115	970
A-7 practice	367	304	310	302	200	244	193	163	2,083
Total	456	401	419	397	339	430	333	278	3,053

[1] Non-additive because of owners participating in more than one practice.

Table 9.—*Comparison of total gross ACP assistance and assistance for ACP forestry practices in east-central Ohio, 1961-64*

Forestry practice	1961	1962	1963	1964	Total
B-10 forestry practices	$ 29,381	$ 47,129	$ 32,506	$ 26,850	$ 135,866
A-7 forestry practice	45,136	33,704	37,435	18,949	135,224
Total	$ 74,517	$ 80,833	$ 69,941	$ 45,799	$ 271,090
Total gross ACP assistance	$855,618	$886,824	$771,549	$741,024	$3,255,015
Percent of forestry practice in total gross ACP assistance	8.7	9.1	9.1	6.2	8.3

Table 10.—*Total ACP assistance for forestry practices in southeastern Ohio, 1957-64*

Forestry practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	$ 4,759	$ 7,779	$ 7,390	$ 5,518	$ 4,179	$10,603	$ 9,070	$ 8,007	$ 57,305
Site preparation	—	—	—	—	1,254	—	—	—	1,254
Pruning	621	545	93	151	557	553	240	304	3,064
Fencing	1,376	1,285	4,910	4,517	5,160	4,502	3,164	2,275	27,189
All B-10 practices	$ 6,756	$ 9,609	$12,393	$10,186	$11,150	$15,658	$12,474	$10,586	$ 88,812
A-7 practice	12,453	11,678	13,391	18,064	19,686	28,958	22,664	17,560	144,454
Total	$19,209	$21,287	$25,784	$28,250	$30,836	$44,616	$35,138	$28,146	$233,266

Table 11.—*Accomplishments under forestry practices of Agricultural Conservation Program in southeastern Ohio, 1957-64*

Forestry practice		1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	acres	348	512	539	380	227	827	722	546	4,101
Site preparation	acres	—	—	—	—	55	—	—	—	55
Pruning	acres	23	36	5	9	19	16	8	12	128
Fencing	rods	1,379	1,198	3,387	3,030	3,987	3,065	2,160	1,515	19,721
All B-10 practices	acres	371	548	544	389	301	843	730	558	4,284
	rods	1,379	1,198	3,387	3,030	3,987	3,065	2,160	1,515	19,721
A-7 practice	acres	484	385	479	687	628	818	624	598	4,703
Total	acres	855	933	1,023	1,076	929	1,661	1,354	1,156	8,987
	rods	1,379	1,198	3,387	3,030	3,987	3,065	2,160	1,515	19,721

Table 12.—*Participation in forestry practices of Agricultural Conservation Program in southeastern Ohio by number of farms, 1957-64*

Forestry practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	21	32	33	18	24	47	32	40	247
Site preparation	—	—	—	—	1	—	—	—	1
Pruning	2	4	2	2	5	5	2	4	26
Fencing	14	12	25	22	29	28	16	13	159
All B-10 practices[1]	31	43	53	37	55	65	44	53	381
A-7 practice	138	81	82	130	102	145	121	110	909
Total	169	124	135	167	157	210	165	163	1,290

[1] Non-additive because of owners participating in more than one practice.

Table 13.—*Comparison of total gross Agricultural Conservation Program assistance and assistance for ACP forestry practices in southeastern Ohio, 1961-64*

Forestry practice	1961	1962	1963	1964	Total
B-10 forestry practices	$ 11,150	$ 15,658	$ 12,474	$ 10,586	$ 49,868
A-7 forestry practice	19,686	28,958	22,664	17,560	88,868
Total	$ 30,836	$ 44,616	$ 35,138	$ 28,146	$ 138,736
Total gross ACP assistance	$421,987	$469,436	$435,895	$388,555	$1,715,873
Percent forestry practice of total gross ACP assistance	7.3	9.5	8.1	7.2	8.0

Table 14.—*Total Agricultural Conservation Program assistance for forestry practices in south-central Ohio, 1957-64*

Forestry practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	$2,851	$ 7,000	$ 9,383	$ 7,631	$ 6,886	$15,853	$18,982	$11,587	$ 80,173
Site preparation	—	20	—	—	—	18	123	—	161
Pruning	—	20	—	—	—	—	115	232	367
Fencing	1,192	1,501	3,174	4,910	2,278	2,289	2,725	4,439	22,508
All B-10 practices	$4,043	$ 8,541	$12,557	$12,541	$ 9,164	$18,160	$21,945	$16,258	$103,209
A-7 practice	2,938	4,009	3,064	2,750	2,955	3,144	3,137	1,674	23,671
Total	$6,981	$12,550	$15,621	$15,291	$12,119	$21,304	$25,082	$17,932	$126,880

Table 15.—*Accomplishments under forestry practices of Agricultural Conservation Program in south-central Ohio, 1957-64*

Forestry practice		1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	acres	287	616	960	1,116	855	1,467	1,510	853	7,664
Site preparation	acres	—	10	—	—	—	1	12	—	23
Pruning	acres	—	10	—	—	—	—	15	12	37
Fencing	rods	1,192	1,320	2,125	3,296	1,876	1,606	1,846	2,959	16,220
All B-10 practices	acres	287	636	960	1,116	855	1,468	1,537	865	7,724
	rods	1,192	1,320	2,125	3,296	1,876	1,606	1,846	2,959	16,220
A-7 practice	acres	107	120	99	111	99	75	86	87	784
Total	acres	394	756	1,059	1,227	954	1,543	1,623	952	8,508
	rods	1,192	1,320	2,125	3,296	1,876	1,606	1,846	2,959	16,220

Table 16.—*Participation in forestry practices of Agricultural Conservation Program in south-central Ohio by number of farms, 1957-64*

Forestry practice	1957	1958	1959	1960	1961	1962	1963	1964	Total
Timber-stand improvement	7	23	31	24	28	51	77	37	278
Site preparation	—	1	—	—	—	1	12	—	14
Pruning	—	1	—	—	—	—	1	2	4
Fencing	7	10	13	20	19	13	14	24	120
All B-10 practices[1]	13	30	37	38	35	58	95	63	369
A-7 practice	30	25	19	24	31	27	17	24	197
Total	43	55	56	62	66	85	112	87	566

[1] Non-additive because of owners participating in more than one practice.

Table 17.—*Comparison of total gross Agricultural Conservation Program assistance and assistance for ACP forestry practices in south-central Ohio, 1961-64*

Forestry practice	1961	1962	1963	1964	Total
B-10 forestry practices	$ 9,164	$ 18,160	$ 21,945	$ 16,258	$ 65,527
A-7 forestry practice	2,955	3,144	3,137	1,674	10,910
Total	$ 12,119	$ 21,304	$ 25,082	$ 17,932	$ 76,437
Total gross ACP assistance	$604,942	$692,119	$655,665	$665,507	$2,618,233
Percent forestry practice of total gross ACP assistance	2.0	3.1	3.8	2.7	3.0

timber-stand improvement, and 264,000 acres require fencing. This represents only 18 percent of the planting, 14 percent of the timber-stand improvement, and 25 percent of the fencing needed in the entire Hill Country.

Only 14 percent of the cost-sharing assistance for forestry practices in the Hill Country is expended in this subregion (tables 14 and 15). Unlike the other subregions, the emphasis is on cultural operations. Some 81 percent of this assistance is utilized for cultural work and only 19 percent for tree planting.

Only 12 percent of the participants in the forestry practices in the Hill Country are in this subregion (table 16). This small number of participants is reflected in the fact that only 3 percent of the ACP assistance for this subregion is applied to forestry practices (table 17).

If the same average annual rate of achievement is maintained (98 acres of tree planting and 965 acres of cultural work), the ACP from 1958 to 1975 will account for 2.3 percent of the estimated tree-planting needs and 8.9 percent of the estimated cultural improvements needed by 1975.

II

FORESTRY PRACTICES OF THE AGRICULTURAL CONSERVATION PROGRAM

A-7 Practice: Tree Planting for Forestry Purposes

Federal cost-sharing will be allowed for the establishment of a stand of trees on farmland for purposes other than the prevention of wind or water erosion. The following are the minimum requirements.

a. The planting must be made in accordance with a plan approved by the local Forest Service representative.

b. Trees must be planted at a rate of at least 680 trees per acre (8-foot by 8-foot spacing or equivalent) and not more than 890 trees per acre (7-foot by 7-foot spacing or equivalent), unless the local Forest Service representative determines that a smaller or larger number is desirable.

c. Plantings must be protected from fire and grazing.

d. Federal cost-sharing may be allowed for permanent fencing (excluding boundary and road fences) where needed to protect the planted area from grazing. Where a fence is necessary, it shall consist of at least three strands of barbed wire or its equivalent, with black locust (or equally durable) posts spaced no farther than 1 rod apart.

e. No Federal cost-sharing will be allowed for planting orchard trees, planting for ornamental shrubs, or planting primarily for Christmas trees.

f. Cost-sharing for replanting may be allowed only when the losses of trees are more than 50 percent due to natural causes over which the farmer has no control, such as extreme drought, insects, diseases, rodents, or fire, other than that due to owner's carelessness. The Federal cost-share is: (1) 80 percent of the cost, not to exceed $3.60 per 100 trees planted, and (2) $1.50 per rod for fencing.

B-10 Practices

Woodland improvement. — For many of the improvement measures listed below, Federal cost-sharing may be allowed, to obtain a fully stocked woodland of high-quality trees. Any woodland that has a continuous or nearly continuous crown cover and then will be managed primarily for successive forest crops is eligible under this practice.

No Federal cost-sharing will be allowed for any area from which merchantable products are harvested in the process of carrying out the practice, unless the Forest Service representative determines that the primary purpose of the operation is to improve a residual stand of trees. The area must be protected from fire and grazing, and domestic animals must be excluded.

The practice must be carried out in accordance with a plan approved by a local Forest Service representative.

a. *Timber-stand improvement.*—The thinning of dense stands and releasing of desirable seedlings and young trees by removing or killing competing and undesirable vegetation shall be done by cutting, girdling, or by chemical treatment of the diseased, cull, or weed trees or other undesirable vegetation. The proper level of good growing stock must be retained.

b. *Site preparation for natural reseeding.*—Federal cost-sharing will be limited to areas: (1) that have a sufficient number of desirable seed trees for natural reseeding; (2) that will not restock unless brush, dense litter, and other material on the forest soil is broken up or removed so that soil is exposed, and (3) on which the seed trees will be left until the area is restocked.

c. *Pruning coniferous stands.*—Federal cost-sharing for pruning crop trees will be allowed only under the following requirements: (1) pruning all dead branches and all live branches up to one-half the height of the tree but not less than 9 feet and not more than 17 feet; (2) a minimum of 150 and a maximum of 250 trees per acre that are well distributed through the stand and that are judged to be final sawtimber crop trees will be selected for pruning, but no cost-sharing will be allowed for pruning any trees over the 250 maximum; (3) pruning must be done with a saw and cuts must be flush with the main stem of the tree; and (4) shaping and shearing trees within stands to be harvested for Christmas trees are not eligible practices.

Technical forestry assistance must be utilized in selecting crop trees.

d. *Permanent fencing.*—Federal cost-sharing may be allowed for permanent fencing (excluding boundary and road fences) where needed to protect the woodland areas for grazing. Where a fence is necessary, it shall consist of at least three strands of barbed wire or its equivalent, with black locust (or equally durable) posts spaced no farther than 1 rod apart.

The Federal cost-share is: (1) 75 percent of the estimated cost of timber-stand improvement; (2) 75 percent of the estimated cost of site preparation for natural reseeding; (3) 75 percent of the estimated cost of pruning coniferous stands; and (4) $1.50 per rod for fencing.

III

CRITERIA EMPLOYED BY THE OHIO SOIL AND WATER CONSERVATION NEEDS INVENTORY

The conservation needs on forest and woodland deal with the problems associated with the development, protection, and management of the forest and soil resources.

Forest land withdrawn from timber utilization, incapable of yielding usable wood products because of adverse site conditions, or so inaccessible as to be unavailable economically was disregarded, except for measures necessary to protect such areas for watershed, wildlife, or recreational uses, or to protect adjacent productive forest and woodland.

Table 18 shows the acreage of forest and woodland estimated to need treatment in each of the following groups:

a. *Establishment and reinforcement of timber-stand.*—The acreage is made up of three components: (1) land that is expected to shift to forest and woodland from other uses by 1975, except the acreage that should be put in trees to check erosion and the acreage needed for shelterbelts and windbreaks; (2) land that was classified as forest and woodland in 1958 but that was less than 10 percent stocked or was stocked with unsatisfactory species; (3) land that was more than 10 percent stocked in forest and woodland in 1958 but needed reinforcement. Ordinarily this did not include any acreage stocked to 40 percent or more. The acreage estimates include only the proportionate part of the acreage needing reinforcement. For example, a total area of 50,000 acres might need reinforcement but the planting needed to accomplish this would be equal to only 35,000 acres of full-scale establishments; thus the 35,000 acres was the amount included in the estimate.

b. *Improvement of timber stands.* This is the 1958 acreage of forest land on which stand-improvement measures are recommended as feasible under good forest management. Estimates were limited to acreages and timber types expected to return the costs of such improvement within 15 to 20 years.

c. *Protection of timber stand from animals.*—This is the acreage of forest land that in 1958 was not receiving adequate protection from animals, including rodents—land on which protection is considered feasible and practical under good forest management. The estimate includes the need for protection from domestic animals.

IV

Table 18.—*Estimated acreage of forest and woodland in the Hill Country of Ohio that needed conservation treatment in 1952, by subregions*

County	Establishment of timber stand	Improvement of timber stand	Protection from animals	Total
EAST-CENTRAL SUBREGION				
Belmont	28,454	56,700	12,000	97,154
Carroll	18,629	69,300	29,500	117,429
Coshocton	25,568	84,950	66,746	177,264
Guernsey	14,000	65,000	59,770	138,770
Harrison	21,000	20,000	27,748	68,748
Holmes	14,050	49,158	32,000	95,208
Jefferson	28,475	70,000	25,000	123,475
Monroe	20,707	65,838	37,000	123,545
Muskingum	20,291	70,200	77,000	167,491
Noble	22,315	41,686	31,768	95,769
Tuscarawas	21,000	38,400	36,000	95,400
Total	234,489	631,232	434,532	1,300,253
SOUTHEASTERN SUBREGION				
Athens	2,000	112,000	50,000	164,000
Hocking	5,000	74,022	57,710	136,732
Meigs	4,800	67,650	44,000	116,450
Morgan	29,954	47,612	35,000	112,566
Perry	18,000	45,860	55,036	118,896
Vinton	15,000	87,800	7,500	110,300
Washington	44,067	110,714	90,089	244,870
Total	118,821	545,658	339,335	1,003,814
SOUTH-CENTRAL SUBREGION				
Adams	1,000	14,000	34,676	49,676
Gallia	14,000	25,000	40,000	79,000
Highland	7,500	12,510	25,020	45,030
Jackson	6,000	13,500	12,574	32,074
Lawrence	12,000	9,000	33,000	54,000
Pike	14,000	30,000	22,000	66,000
Ross	20,300	40,500	81,000	141,800
Scioto	2,350	50,000	16,000	68,350
Total	77,150	194,510	264,270	535,930
All subregions ..	430,460	1,371,400	1,038,137	2,839,997

Source: Reeser, Robert M., *Ohio Soil and Water Conservation Needs Inventory.* Ohio Agricultural Extension Service.

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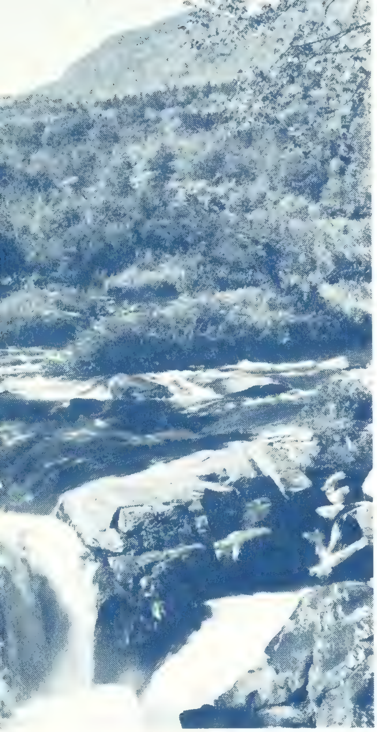

Increasing WATER YIELD in the Northeast by management of forested watersheds

by Howard W. Lull
and Kenneth G. Reinhart

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Increasing WATER YIELD in the Northeast by management of forested watersheds

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Preface

THIS research paper is designed to answer some of the questions of forest watershed managers interested in possibilities of increasing water yield through management and removal of forest cover. Water shortages from the recent drought and the growing interest in the subject of forest water-yield management, as evidenced in the Municipal Watershed Management Symposium held at the University of Massachusetts in 1965, make this paper timely.

To take advantage of the moment we have utilized and extrapolated what information we have so we can set forth management possibilities. Common knowledge for years has held that forest cover and water yield are inseparably connected. Here we suggest how forest cover may be employed to increase water yields. We do not have all the answers for management. In a few years current research programs will provide many of them. Meanwhile, though we see through our glass darkly, we see enough to make a beginning.

MORE WATER BY CUTTING TREES

INCREASING demands on water resources from all elements of population and industry in the Northeast and forecasts of even greater demands in the future, plus concern over the drought of the past 4 years, have stimulated a search for additional water sources. Sea water, cloud-seeding, and long-distance piping of water from areas of surplus to areas of shortage have been suggested and are being tried or studied. This paper describes the possibilities of increasing water yield in the Northeast by a method that has received little attention—by cutting trees.

Most kinds of vegetation use large amounts of water, but trees use the most. Canopies of mature hardwoods and conifers extending 40 to 80 feet or more into the air intercept rainfall and snow and draw moisture from the soil. The canopy's leaf surface may be as much as five times the land area occupied by the tree. Each square inch of the underside of leaves may possess a few hundred thousand stomates through which water vapor emerges into the atmosphere. Powering this movement is radiant energy: shortwave radiation received and not reflected from the leaf surface, and longwave radiation from cloud and ground. As long as the soil is wet, evaporation of moisture from the stomates into the atmosphere is the first use to which the energy is put.

Snow presents a special situation. Trees affect snow accumulation, evaporation, and melting. Of particular importance are the functions of conifer canopies that serve to intercept snow, to shade the snow below, and to slow its melting.

Thus, in the forests of the Northeast, 40 to 60 percent of all precipitation that falls is returned to the atmosphere by evaporation or transpiration and never reaches the stream or groundwater.

This presents an opportunity and a challenge: Can we reduce the amount evaporated to the atmosphere and thus increase the yields available for domestic, industrial, and other uses? Research results from all over the world, including some from the Northeast, indicate that we can. Removal of all or part of the forest, by cutting or use of herbicides, can accomplish this. The amount and duration of the increase depend on the kind of treatment, the ground cover that develops, and upon soil, weather, and other factors.

When trees are cut or killed, the principal mechanism for moisture movement from soil to atmosphere is destroyed. Evaporation from slash, litter, and the soil surface and transpiration from a shallow-rooted ground cover become the only means for moisture movement skyward; the upward movement of water through the soil is slowed. As a result, less water is lost and the soil remains moist; a smaller amount of subsequent rainfall is required to recharge the soil and a larger proportion finds its way to the stream.

Forest regeneration can rapidly re-establish conditions that prevailed before cutting. Sprout growth, utilizing previously developed root systems, and invasion of herbaceous vegetation can in a matter of 2 to 3 years re-establish transpiration and sharply curtail the yield increase (Kovner 1956; Reinhart et al. 1963).

The Northeastern United States (fig. 1)—Maine to West Virginia—offers perhaps more opportunities for forest water-yield management than any other region. It has a tremendous concentration of population and a sizable forest area. The Northeast has 6 percent of the total area of the United States, 28 percent of its total population, and 15 percent of its total commercial forested area. It has about 400 municipal watersheds and reservoir forests

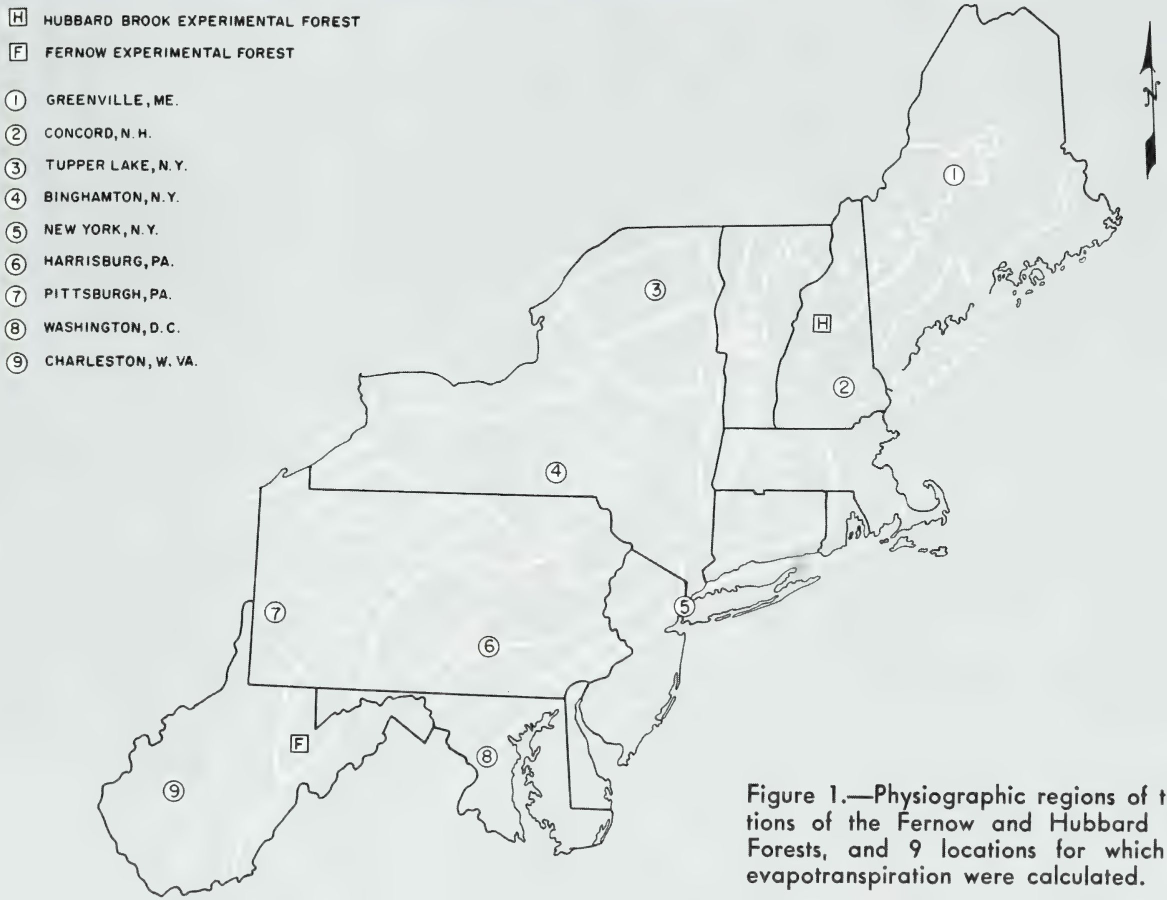

Figure 1.—Physiographic regions of the Northeast, locations of the Fernow and Hubbard Brook Experimental Forests, and 9 locations for which transpiration and evapotranspiration were calculated.

(well over 1,000,000 acres of forest land) that serve about one-third of the region's population. Because it has sufficient precipitation and solar radiation, evapotranspiration from the forest is great enough to permit sizable increases in water yield from forest cutting.

Highly populated and industrialized, the Northeast has great water demands, and they will very likely increase as population rises and as the water supply and labor force continue to attract industry. These increasing demands may yet turn municipal bureaus of water supply to cutting forested watersheds for additional water.

On a per-capita basis the Northeast has about one-fifth of the precipitation and one-third of the runoff of the 11 Western States, which are generally considered to be the water-short region of the country. Western runoff averages about 5.5 inches annually (Munns 1952) compared to 18 inches in the Northeast (Lull 1966); in the West the population density is about 23 water-users per square mile; in the Northeast, 251. In the Northeast used water may be re-used; whereas in the West about 90 percent of the water is used in irrigation and about two-thirds of this is lost to the atmosphere.

The purpose of this research paper is to present some of the methods by which water yields can be increased from forested watersheds and to discuss the effectiveness of these methods under different conditions. Methods discussed include clearcutting, partial cutting, and use of herbicides. Effectivness during drought is considered. Effects on water yield of reforestation, forest protection, and forest fire and other destructive agencies are discussed. And, finally, safeguards for water quality are considered.

Cutting trees on a watershed to increase water yield, as advocated here, is not so much a departure from time-honored concepts of the protective role of the forest in regard to streamflow and erosion as it is a recognition of the growing stature of the multiple-use concept that forest land is useful and can be managed for water, wildlife, and recreation, as well as for timber. To still incipient alarm as to possible flood and erosion damages from the procedures set forth, or destruction of scenic values, the authors would like to stress initially that: (1) forest cutting for water-yield increases must be followed by development of sufficient ground cover to protect the site: (2) water management on an intensive basis, involving clearcutting to obtain maximum water yields, would be limited in area and practiced only by some municipalities, those requiring additional water supplies; and (3) extensive water management through practice of a sustained-yield program of forest management is possible and productive both in timber and water. We believe that the forests of the Northeast, extensive in area and well-distributed throughout the region offer, in certain situations and selected areas, possibilities for management to increase water supplies.

TOTAL FOREST REMOVAL

Here we are concerned solely with means of obtaining a maximum increase in water yield from total forest removal (clearcutting or other methods of killing all vegetation). In the next major section, on partial forest removal, we discuss the possibilities of increasing water yield under a sustained-yield program of forest management.

Amount of Increase

Removal of all vegetation on a well-stocked forested watershed in the Northeast will increase annual water yield the first year after treatment by about 4 to 12 inches. Justification of this estimate rests on: (1) a first-year increase of 5 inches[1] at the Fernow Experimental Forest in West Virginia after removal of 80 percent of the basal area (Reinhart et al. 1963) and, more recently, an increase of 12 inches after total clearcutting and herbicide spraying; (2) increases of 5 to 16 inches at the Coweeta Hydrologic Laboratory in North Carolina after clearcutting mature hardwoods (Hewlett and Hibbert 1961); (3) and the following conservative estimates of the effects of clearcutting, in inches of water increase per year, for a number of points across the Northeast (fig. 1):

---

[1] 1 inch = 27,154 gallons per acre.

Location	*Water increase (inches)*
Greenville, Me.	4
Concord, N.H.	8
Tupper Lake, N.Y.	5
Binghamton, N.Y.	10
New York, N.Y.	12
Harrisburg, Pa.	11
Pittsburgh, Pa.	12
Washington, D.C.	13
Charleston, W. Va.	13

These values are estimates of annual forest transpiration based on calculations of potential evapotranspiration from annual temperature and precipitation, followed by estimates of actual evapotranspiration and its division into evaporation and transpiration (Holdridge 1962). Forest removal eliminates forest transpiration, reduces interception, and increases evaporation from the soil, the net result giving a conservative cast to the above estimates of water-yield increases from transpiration-only savings. As is evident, these estimates are strongly related to latitude and temperature. The effect of total forest removal obviously must depend on the kind of forest present before cutting. Maximum results should be expected only when the forest fully occupies the site; where regrowth before treatment has not yet filled voids from earlier cuttings or from fire, insects, or diseases, less than maximum increases can be expected.

Four of the five inches of annual increase from commercial clearcutting at the Fernow Forest came in June, July and August (precipitation after treatment was far above average: the 3-month total was 27.6 inches). In the case of the 12-inch increase from a recent total clearcutting, 39 percent came in June, July, and August (the 3-month precipitation was 13.4 inches); 72 percent of the 12 inches came in the period June through November. This relatively quick response to reduction of evapotranspiration in the growing season is, we believe, in keeping with the shallow soils (2 to 5 feet deep) of the area. At Coweeta, where the soils are much deeper, more of the increase from clearcutting was delayed until the winter months.

Forested mountains of the Northeast (the White Mountains, Green Mountains, Adirondacks, Allegheny Plateau and Mountains, and the Ridge and Valley Province [fig. 1]) make up 57 percent of the region and have shallow soils of depths similar to the Fernow watershed. Much of the glaciated New England Upland also has shallow soils. Deep-soil areas are confined mostly to the Piedmont and Coastal Plain, the Connecticut Valley, and the Great Lakes Section in New York State, the major non-forest areas of the region.

Accordingly, we believe that in much of the Northeast any increases in water yield due to clearcutting will probably appear mostly in summer or early fall. In areas of accumulated snowpack (northern New York, Vermont, New Hampshire, and Maine) increases from reduced snow interception would appear in spring runoff.

Below- and Above-Normal Precipitation

Clearcutting a forested watershed during a drought will provide little relief. The upland soil is already dry; transpiration is at a minimum; and existing low streamflow comes from groundwater. Tree-cutting in this situation would cut off the low rate of transpiration, but would not provide greater water supplies for streamflow.

However, as soon as rainfall or snowmelt had recharged the soil (with an amount of water that will not necessarily break the drought), clearcutting would become effective, providing opportunity for greater proportions of subsequent rainfall to go into streamflow. Thus during a drought summer removal of the upland forest would not increase water yield, but the recharginng of the soil by winter precipitation and snowmelt (when, because of low evaporation, below-normal amounts of precipitation may be sufficient for recharge) would create the opportunity for greater water yield from spring and early summer rainfalls.

An exception to this is the cutting of riparian areas where even in drought trees with their roots tapping groundwater supplies may be transpiring heavily. Cutting these trees would effectively increase water yield, the amount depending on the proportion of the watershed occupied by riparian vegetation. Generally, in the Northeast, riparian areas occupy only a small part of forest-covered watersheds.

The drought of the past 4 years has raised the question whether periods of drought could be predicted with sufficient accuracy to permit forest harvesting just before or during dry cycles to produce water-yield increases when they are most valuable. Possibilities of predicting dry periods from sunspot activity have been studied for many years. Sunspots reach a maximum, on the average, every 11.3 years; some cycles are as short as 7 years and some as long as 17 (Tannehill 1955). Recent studies have shown that, though the energy received from the sun does not change to any extent during a sunspot cycle, these cycles appear to be related in some unknown way to the large-scale circulation of the atmosphere. This in turn is responsible for changes in local weather (MacDonald 1959). No generally accepted method of predicting solar variations has been developed that would permit forecasting droughts. Expected frequency and severity of droughts may be calculated from past records of precipitation and streamflow (nationwide, droughts have occurred about every 5 or 6 years) but exactly when and where droughts will occur cannot yet be predicted with any accuracy.

Below- or above-normal annual precipitation after forest removal will not have a pronounced effect on water-yield increases in the humid East. For instance, the greatest first-year increase experienced, the 16-inch increase from Coweeta's watershed 17, came during a period of below-normal precipitation—55 inches as compared with the normal annual of 74 inches. In the other direction, the 5-inch increase from the commercial-clearcut watershed at the Fernow, certainly not an exorbitant amount, came during a year of greater-than-normal rainfall—63 inches compared to the normal annual of 58 inches. However, in both of these high-rainfall areas, potential and actual evapotranspiration are very close and the below-normal precipitation still produced the continual soil wetness necessary for actual evapotranspiration to approach closely the potential.

The effects of normal and above- and below-normal growing season precipitation on water-yield increases due to clearcutting were estimated from the Fernow data by Lull and Sopper (1966c), using the Thornthwaite and Mather (1957) procedure.

Monthly water surpluses were computed from a daily water balance based on an estimated reduced potential evapotranspiration after clearcutting. Actual daily rainfall values were used for highest, lowest, and mean records, and the mean record was adjusted to give mean monthly totals. Water surpluses were given as follows:

	Rainfall (*inches*)	*Water surplus* (*inches*)
Highest (1958)	37.71	4.95
Lowest (1952)	20.81	3.34
Mean (1959)	28.44	3.03
Adjusted (1959)	29.88	4.39

The greatest surplus, 4.95 inches, the first year after cutting was associated with the highest rainfall of record. The effect of rainfall distribution is brought out in surpluses of 3.03 and 4.39 inches for mean rainfalls with different distributions. Note that the surplus from the lowest rainfall of record was 0.31 inches greater than that for the mean rainfall, again the result of different distribution of daily rainfall. Examination of these values suggest that differences in amounts of rainfall up to 17 inches during the growing season may produce differences in water surpluses of 1 to 2 inches.

Methods of Treatment

The total forest can be removed by timber cutting, use of herbicides, burning and bulldozing, or combining these treatments in various ways. After removal of trees and understory woody vegetation and before the protective forest floor deteriorates, growth of ground cover should be encouraged to maintain the stability of the site.

Timber cutting.—The most direct and common method of forest removal is by cutting the trees. Usually this can be accomplished by a logging operation that produces sawlogs, pulpwood, or other products whose sales more than covers the cost of the operation. However, for total forest removal there is usually some material to cut that is unmerchantable because of size or quality. This involves an out-of-pocket cost. When such material is cut, it is usually left on the ground.

Complete removal can be accomplished by cutting, but herbicides may be more practical for killing small woody stems and useful for preventing or reducing sprouting of hardwoods.

Cost of clearcutting varies widely depending upon the volume of timber cut and the methods used. Recently at the Hubbard Brook Experimental Forest in New Hampshire an unmerchantable stand of northern hardwoods (averaging 75 square feet of basal area per acre) was contract-cut for $170 per acre. Trees were felled and left lying. Slash was lopped off to a height of 3 feet or less. The operation required 4 man-days per acre; cutters who furnished their own power saws earned $4 per hour.[2] In 1962-63 at the Coweeta Hydrologic Laboratory in western North Carolina, two oak-hickory watersheds were clearcut, without removal of the felled trees, at per-acre expenditures of $112 and $128 and 8.8 and 10.3 man-days.[3] Details are given in the appendix.

Clearcutting after removal of merchantable material naturally is less expensive. In western North Carolina it has cost from $47 to $65 per acre (4.5 man-days per acre for the latter figure) and $37 to $60 per acre when clearing with a specially designed tractor-mounted blade. In another instance an intensive cleaning in an 11-year-old hardwood stand required 7.3 man-days per acre.[4] Further details are given in the appendix.

Herbicides.—There is a considerable backlog of experience on the use of herbicides in forest stands. However, herbicides have been used mostly for silvicultural reasons—usually to kill individual undesirable trees or some undesirable component of the stand. Their use to kill vegetation for water-management purposes has so far been limited mainly to experimental areas; thus methods of application have been considerably different and costs much higher than would be expected in routine applications.

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[2] Communication of February 23, 1966, from R. S. Pierce, project leader, watershed management research, Northeastern Forest Experiment Station, Durham, N. H.

[3] Communication of February 21, 1966, from James E. Douglass, project leader, watershed management research, Southeastern Forest Experiment Station, Franklin, N. C.

[4] Communications of February 28, 1966, from Richard F. Harlow, wildlife research biologist, Southeastern Forest Experiment Station, Asheville, N. C., and of March 4, 1966, from Charles E. McGee, project leader, U. S. Forest Service, Asheville, N. C.

Early tests have shown that very little, if any, of the herbicide applied to watersheds reaches the water supply (see pages 32 and 33). However, as a necessary precaution, their use should be governed by recommendations of state authorities responsible for coordinating use of these chemicals. These officials are usually associated with state agricultural experiment stations.

The current rate of development of new herbicides and methods for their use is almost phenomenal; prospects for increased efficiency and lower cost are good.

Killing individual trees.—Frill girdling, with application of 2,4,5-T or ammate to the frill, and stem injection appear to be the most economical methods for treating individual trees. Costs for killing all trees may range from $0.003 to $0.010 per inch of diameter or about $10 to $30 per acre. A review of several studies is given in the appendix.

Foliar sprays.—Peevy (1960) found that foliar spraying from the ground cost $22 per acre with ammate and $12 with 2,4,5-T. Labor costs were $1.25 per hour; 2,4,5-T cost $8.50 per gallon, and ammate $0.24 per pound. MacConnell (1962) reported costs of $6.17 to $10.73 per acre depending on concentration of the herbicide. The shoulder-mounted mistblowers used had effective ranges of 30 feet in quiet air. Oak was most susceptible and resprouting was abundant only from aspen and red maple. For total kill of vegetation within reach of a mistblower, costs of $15 to $20 seem logical when 2,4,5-T is used. Little and Mohr (1964) estimated that a combination of mistblowing and subsequent injector treatment of surviving hardwoods would cost about $15 and $18 per acre respectively.

Aircraft spraying is the least expensive method. For fixed-wing aircraft Peevy (1960) reported costs of $7.50 to $9.00 per acre using 2 pounds of 2,4,5-T, and Butler et al. (1963) reported a cost of $4.96 per acre for application of 1 pound of 2,4,5-T. Helicopter costs may depend largely on the proximity of the job to the machine headquarters. For instance, a recent aerial spraying of hardwoods on a relatively isolated area on the Monongahela National Forest in West Virginia cost $23 per acre, of which

$19.50 was the cost of the helicopter; whereas spraying easily reached New Jersey woodlands cost $9.10 per acre, of which about one-half was for the helicopter. In a 600-acre test in Tennessee, helicopter spraying of 2,4,5-T killed 85 percent of the low-grade hardwoods larger than 2.9 inches d.b.h. at a total cost of $8.85 per acre (Russell 1961).

Aerial treatments are mostly effective on overstory vegetation and must be supplemented by tree injection or mistblowing or both if all vegetation is to be killed.

Soil sterilants.—A number of chemicals have recently been introduced that eliminate vegetation for one to several years by their sterilizing effect upon the soil. They may be sprayed on the soil surface or broadcast as pellets, and they become effective when sufficient rainfall carries the chemicals to the root zone. Pelletized chemicals are more readily applied than the sprayed solutions, particularly in rough terrain, and will not drift and damage neighboring vegetation. Greater rates of application are required for deeper rooted vegetation. Possibilities of overland flow and erosion after protective vegetation is killed strongly suggest that sterilants be used with caution and at first only on an experimental basis.

Other methods.—Controlled burning using hot summer fires provides, in some situations, an inexpensive way of killing worthless hardwoods. In the New Jersey pine region Little and Moore (1953) found that, on medium wet and dry lowlands, hot summer fires killed or killed back all hardwoods and a large proportion of pine. Their control required 1 to 5 man-hours per acre. Light summer and winter fires were not as effective. Light summer fires killed 63 to 100 percent of the hardwoods and 40 percent of the pines. In one study, controlled winter burning killed all hardwoods below 0.6 inch in diameter but only 12, 2, and 1 percent of the 1-, 2-, and 3-inch trees respectively, and nothing any larger (Little et al. 1948). Fire used after logging to kill residual non-commercial material may be particularly effective because of fuel added by logging slash. One of the problems with hot summer fires is the necessity of always being ready to take advantage of infrequent periods of suitable fuel and weather conditions.

Bulldozing has little to recommend it. Costs are high, $35 to $60 per acre; and on sloping lands erosion can result, particularly from dormant-season operations (Carvell and Goodspeed 1962; Little and Mohr 1964). Sprouting may be so abundant that further treatment, burning or herbicidal treatment, is required.

Generally, burning and bulldozing, if used, should be confined to sites on the Coastal Plain where topography and soils limit overland flow and erosion.

Cutting and herbicides.—A combination of cutting and herbicides may be most practicable to achieve total forest removal. At the Fernow Experimental Forest, two watersheds were cleared in four steps: (1) before a commercial clearcutting, all trees above 1 inch d.b.h. were basal-sprayed with 2,4,5-T in diesel oil; (2) sawlogs and pulpwood were removed; (3) all remaining trees over 20 feet in height were felled; and (4) foliage was sprayed, using a backpack mistblower, in early summer and in late summer with 2,4,5-T in diesel oil and water (Reinhart 1965). Man-days per acre for the various operations (except the commercial clearcutting) were as follows:

1. Basal spray before logging	1.7
2. Cutting residuals	.5
3. Foliage spray	1.0
	3.2

With an 8-hour day and labor costs of $2 per hour, this would amount to $51 per acre. Herbicides and oil cost about $15 per acre. Because this operation had a research objective of determining water-yield increases after removal of *all* vegetation, the costs were higher than those expected when the operation is in practical application.

Total cost of obtaining increased yields will depend not only upon costs of initial treatment and maintaining the treatment, but also on the loss of income from timber growth. Cost estimates calculated for the commercial clearcutting on the Fernow provide an example. For this type of cutting no costs need be assessed for the initial treatment. Maintenance cost for application of herbicides every 5 years to kill small trees and low vegetation was estimated at $1.80 per acre per year. Timber income foregone was estimated at $4 per acre per year. For an estimated average annual increase in water yield of 144,000 gallons per acre (5.3 area-inches), the total cost per thousand gallons would be $0.04 (Trimble et al. 1963). Subsequent experience with vegetation regrowth indicates that these may be optimistic estimates for amount of increase as related to costs. Even so, this treatment is probably competitive with costs of other methods of increasing water supply.

Summary of costs.—Experience in forest removal, both by use of herbicides and by other methods, has been of limited scope and applicability, gained mostly from a few timber-management operations or watershed experiments. Thus the cost picture is not very clear. Better cost estimates must await pilot-scale tests of actual water-yield treatments. Even then, costs may vary widely with local conditions.

Present estimates of per-acre costs of removing fully stocked non-commercial stands show a wide range, about as follows:

Clearcutting	$100-$200
Herbicidal treatment:	
Frilling and poisoning	$10-$30
Tree injection	$10-$20
Foliar sprays, ground	$15-$20
Foliar spray, aerial	$5-$25
Controlled burning	$2-$10
Bulldozing	$35-$60

These treatments may not be completely effective. Often two or more may have to be used in combination, or re-treatments must be made. Two or more foliar sprayings may be required to kill all sprout growth from clearcutting; controlled burning may not kill the larger trees so that additional frilling and poisoning may be necessary. When the proper combination of treatments is used most of the vegetation, perhaps 75 percent, should be effectively killed by the initial application.

A commercial clearcut may have to be followed by cutting residuals. Costs can range from $35 to $65 per acre; frill-girdling or stem injection plus mist-spraying smaller material may cost about $30 per acre.

Maintaining Maximum Yields

Regrowth begins soon after timber is removed, or during its removal, depending on the season of the year. Regrowth can rapidly reduce water-yield gains experienced the first year as shown in the estimated regression of annual water yields in inches during the 10 years after clearcutting watershed 1 at the Fernow and watershed 13 (north-facing) at Coweeta (Kovner 1956; Lull and Reinhart 1966).

Years after cutting	*Fernow (inches)*	*Coweeta (inches)*
1	5.1	14.7
2	4.0	12.0
3	3.0	10.5
4	2.4	9.4
5	1.8	8.6
6	1.4	7.9
7	1.1	7.3
8	.8	6.8
9	.6	6.3
10	.5	5.9

This reduction in yield may be expressed in terms of the height of the vegetation, assuming full stocking of sprouts and seedlings. For the Fernow, the average annual height of forest regrowth the 7 years after cutting, and concurrent reductions in water yield, are given in table 1. Similar data are given for Coweeta watershed 13, based on Kovner's (1956) analysis of recession in water yields after regrowth and a height-growth curve for upland oak with a site index of 70 (Schnurr 1937).

In the 7 years a height growth of 18 feet at the Fernow was related to a reduction in increased yield of 78 percent. At Coweeta the same percentage reduction was equivalent to a height growth of 36 feet in 20 years. Thus at Coweeta it took about three times longer and twice the height growth to reduce yield proportionately to the Fernow reductions. Soil moisture-storage between field capacity and wilting point in the Fernow watersheds is about 4.5 inches (Reinhart 1964a), or an average soil depth of 30 inches dried to wilting point; soil depth to bedrock ranges from 2 to 5

Table 1.—*Average height of forest vegetation after clearcutting, and concurrent increase in water yield*

Fernow Experimental Forest			Coweeta Hydrologic Laboratory		
Year after clearcutting	Height of vegetation	Increase in water yield	Year after clearcutting	Height of vegetation	Increase in water yield
	Feet	*Inches*		*Feet*	*Inches*
1	4	5.1	1	4	14.7
2	8	4.0	2	8	12.0
3	11	3.0	3	11	10.4
4	13	2.4	4	13	9.4
5	15	1.8	5	15	8.6
6	17	1.4	—	—	—
7	18	1.1	—	—	—
—	—	—	10	21	5.9
—	—	—	15	29	4.5
—	—	—	20	36	3.3
—	—	—	25	42	2.4
—	—	—	30	48	1.8
—	—	—	35	54	1.0
—	—	—	40	60	.6
—	—	—	45	65	.2
—	—	—	50	70	.0

feet. At Coweeta roots are located mostly in the top 4 or 5 feet of soil, but occasional roots have been observed as deep as 20 feet (Hewlett and Hibbert 1961). Because of this greater depth, it takes longer than at the Fernow for roots to reoccupy the soil mass, and this may be one reason why increased water yield is prolonged.

A foliar spray would probably be the most efficient way of maintaining maximum yields. Data in table 1 suggest that mist-blowing would be necessary annually or every other year at the Fernow and perhaps every third year at Coweeta. The percent of the maximum increase obtainable from killing of vegetation at 1- to 5-year intervals would be as follows:

Year	*Fernow (percent)*	*Coweeta (percent)*
1	100	100
2	89	91
3	79	84
4	71	79
5	64	75

The cost of spraying woody regrowth would depend on its size and density. Little information of this kind is now available. As already noted, it cost $66 per acre for basal spraying, cutting of residuals, and foliar spraying with a backpack mistblower for the initial treatment on two Fernow clearcut watersheds. The next growing season, foliage spray was applied to considerable regrowth, including a volunteer growth of herbs and grasses, at a cost of $40 per acre ($19 for labor at $2 per hour and $21 for chemical). Such a thorough and expensive job would probably be too costly for practical water management. A more realistic estimate is the $5 to $25 per acre cost of foliar spraying given previously.

Maintaining a non-forest raises questions of site deterioration and water-quality effects. Annual regrowth cut clearly for 15 years on watershed 17 at Coweeta gradually produced a closed cover of herbaceous and low shrubby growth over the soil. Storm peaks and sedimentation were not increased at all (Dils 1957). Herbicidal treatment of annual growth with 2,4,5-T or 2,4-D would have a more drastic effect but moderated to the extent that the area would be invaded by grasses that are not susceptible to these chemicals. Periodic application of soil sterilants to keep a watershed entirely free from vegetation would be undesirable, for it would ultimately result in decay and disappearance of the forest floor with consequent exposure to rainfall impact, soil compaction, overland flow, and erosion.

To prevent erosion and maintain high water quality, some type of ground cover must be allowed to develop after total forest removal. Recent experience at the Fernow has indicated that clearcutting and herbicidal treatment of the understory is followed by a rapid invasion of herbaceous vegetation. We know very little about natural invasion of a ground cover, its rate, species, water-use, and soil-holding properties. Possibilities of seeding clearcut and herbicide-treated areas to get desirable cover must be investigated. For purposes of water use, shallow-rooted vegetation — preferably low-growing and with a short growing season—would be best. For watershed managers an evaluation of water use of herbaceous vegetation would be helpful.

Management of Reservoir Shorelines

On most municipal reservoirs the forest cover extends to the shoreline though there are instances where shoreline forest has been cut to reduce transpiration losses or to facilitate detection of trespass. Many shoreline areas have been planted to conifers as a screen to prevent hardwood leaves from blowing into the reservoirs and discoloring the water.

The amount of water transpired by forest vegetation growing along shorelines has never been determined. Obviously however, within the area in which the roots reach the groundwater extending from the reservoir, transpiration must be at a maximum. The difference in evapotranspiration from reservoir shorelines and from the upland forest above the shorelines may be estimated as the difference between potential evapotranspiration (not limited by deficiences in soil-moisture) and actual evapotranspiration (with occasional deficiences in soil-moisture) as can be approximated by the procedure developed by Holdridge (1962). Approximate annual evapotranspiration values for selected points in the Northeast are as follows:

Location	*Potential (inches)*	*Actual (inches)*	*Difference (inches)*
Greenville, Me.	10.04	8.63	1.41
Concord, N. H.	16.50	15.34	1.16
Tupper Lake, N. Y.	12.01	10.93	1.08
Binghamton, N. Y.	21.65	19.27	2.38
New York, N. Y.	27.60	23.74	3.86
Harrisburg, Pa.	27.09	22.20	4.89
Pittsburgh, Pa.	28.73	22.87	5.86
Washington, D. C.	31.97	25.90	6.07
Charleston, W. Va.	30.67	26.06	4.61

On a per-acre basis these differences range in equivalent water volumes from 38,287 gallons for Greenville, Me., to 164,825 gallons for Washington, D.C. As to magnitude of shoreline forests: a square-shaped reservoir with a water surface of 10 acres and a perimeter of 2,640 feet with a shoreline forest 200 feet in depth would have 12 acres of forest.

To reduce excessive water losses along shorelines, the forest cover should be cut back to a line perhaps 10 to 15 feet above the water table, and a herbaceous ground cover should be allowed to develop. The distance will depend on the slope of the water table and the slope of the land. Thus, if the water table slopes 5 percent to the reservoir, and the land surface slopes 10 percent, a line 10 feet above the water table would be 200 feet back of the shoreline. Cutting the forested shoreline may not be entirely advantageous. Tree removal will reduce shading of the shallow water at the lake margin and increase windflow over the lake, which will often bring in advected heat and facilitate turbulent exchange of water vapor. The extent of these effects is not known.

Water Harvesting

It is conceivable that the ultimate stage of water-yield management after forest removal would be water harvesting by treating the soil to increase rainfall runoff. By constructing an impermeable surface, almost all rainfall can be realized as runoff. Forest watersheds in the Northeast yield as runoff from 40 to 60 percent of the precipitation. Clearcut they may yield 70 percent; with a soil treatment perhaps 90 percent.

With 40 inches of annual precipitation and 90 percent recovery, each square foot of impermeable surface can produce 22.4 gallons of water; each acre can produce 977,486 gallons, and each square mile 625,600,000 gallons, a volume sufficient to provide 100 gallons daily for 17,000 people. On this basis the Pequannock watershed of Newark, N. J., 36,000 acres of forest land, if treated for water harvesting could meet the water needs of 964,000 people if ample storage could be provided.

Current research suggests that treatments can be developed to waterproof and stabilize the soil surface for an annual cost of 2 cents per square yard. Clearing, smoothing, and rolling the site preparatory to treatment costs 5 cents per square yard (Myers 1963). Recovering 90 percent of 40 inches of annual rainfall at a treatment cost of 7 cents per square yard the first year, 4.5 cents the first 2 years, 3.7 cents the first 3 years, and 2.5 cents the first 10 years, would be equivalent to a water cost of 35, 22, 18, and 12 cents per 1,000 gallons, respectively. Stabilizing the channel from the collection site to the reservoir would be a necessary additional cost.

The least expensive treatment developed to date, according to Myers (1963), is an asphalt spray that should have an annual cost of $0.03 per square yard or less. Other materials are considerably more expensive. One-mil aluminum foil can be bonded to the soil with an asphaltic emulsion for about $0.25 per square yard. Thirty-mil butyl rubber sheeting costs about $1.60 per square yard and has an expected life of over 10 years. Vinyl and polyethylene plastic sheeting have proved unsatisfactory.

According to Myers (1963), wide-scale application of water-harvesting principles seems certain to develop within the next decade. Certainly, the costs seem to be competitive with other methods. Water harvesting probably would not be feasible on the steep and rocky slopes that comprise much of the forest land in the Northeast. The requirement of clearing, smoothing, and rolling preparatory to spraying the impermeable surface suggests that gently sloping pasture or cropland close to reservoir storage would be more suitable. Water harvesting is still in an experimental stage regarding soil-sealing methods, their costs and duration, and the maintenance of site and channel stability.

PARTIAL FOREST REMOVAL

Here we are concerned with increase in water yield that may be achieved from timber management under a sustained-yield program in which only part of the timber on a watershed is removed. In this situation we must consider both timber and water together. Timber management and water-yield effects cannot be considered separately, for the harvesting of forest products will, to some degree, reduce interception and transpiration and thereby affect water yield.

The magnitude of the effect, under a sustained-yield program, depends largely on whether all-aged management or even-aged management is employed. All-aged management that involves harvesting of mature trees by individual selection will have a small effect on water yield, as we will show. Even-aged management that involves clearcutting of selected areas will have a greater effect, its magnitude depending on the proportion of the watershed area cut and the size of individual clearings. Thinnings and improvement cuttings will, like selection cuttings, generally have a minor effect. In some instances, herbicides may be used to improve a stand by treating certain components or areas.

All-Aged Management

The only examples of the effects of all-aged management on water yield in the Northeast come from the Fernow Experimental Forest where in 1958-59 three experimental watersheds were partially cut. In one, subjected to a diameter-limit cutting, every merchantable tree of long-lived species above 17.0 inches d.b.h. and every tree of short-lived species larger than 7.0 inches were cut and culls above 17.0 inches d.b.h. were killed. In a second watershed, under extensive selection, harvesting and killing of culls were limited to marked trees larger than 11.0 inches d.b.h. In the third, under intensive selection, cutting and cultural work were limited to selected trees above 5.0 inches d.b.h. (Reinhart et al. 1963). These last two practices employed individual-tree selection.

The severity of the cutting and the size of the increases in annual and seasonal yield are given in table 2. Annual increases were related to the amount of timber cut and culled and came mostly during growing seasons. They were but fractions of the annual increase of 5.1 inches from the commercial clearcut watershed on the same experimental forest. First-year annual increases were 10.0, 2.4, and 1.3 percent of predicted annual runoff from the diameter-limit, extensive, and intensive treatments respectively (as compared to 19.2 percent for the commercial clearcut); and growing-season increases amounted to 52.9, 33.3, and 8.8 percent. In volumes of water, annual increases were equivalent to 68, 19, and 8 thousand gallons per acre. These increases persisted for barely more than a year.

First-year increases from partial cuttings at the Fernow Experimental Forest correspond roughly to first-year increases from six watersheds of southerly aspect at Coweeta (Hewlett and Hibbert 1961). Five of these six had ratios of increased annual yield in inches to percent of basal area cut of 0.03 to 0.07 (the sixth had 0.00); two of the four treated Fernow watersheds had ratios of

Table 2.—*Cutting and water-yield changes in three watersheds at the Fernow Experimental Forest*

Watershed treatment	Gross timber volumes[1]			Water yield changes					
	Original	Cut and culled	Residual	1st year		2nd year		3rd year	
				GS[2]	DS[2]	GS	DS	GS	DS
	M bd. ft.	*M bd. ft.*	*M bd. ft.*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Diameter-limit	7.1	4.2	2.9	1.8*	0.8	0.7*	0.8	—0.2	0.5
Extensive selection	12.0	3.7	8.3	1.4*	—.6	—.3	.3	.0	—.7
Intensive selection	8.3	1.7	6.6	.3	.0	.4	.9	—.1	.4

[1] Gross volumes in thousands of board feet per acre to 8-inch top, including volume in cull trees.

[2] GS = growing season (May to October); DS = dormant season (November-April).

* Increase statistically significant at the 5 percent level.

0.06 to 0.07 and two had ratios of 0.02 and 0.03. Ratios for northerly aspect watersheds at Coweeta averaged 0.15; the difference is under study.

Increases in water yield at the Fernow Experimental Forest from partial cuttings, like the increases from clearcutting, are probably close to the maximum for the region. Increases in the Adirondacks and northern New England may be one-third to one-half those in West Virginia (see tabulation, p. 6). Region-wide, partial cutting under all-aged management can have only a small and short-lived effect on water yield.

Even-Aged Management

In even-aged management the situation is quite different because harvest cuts under this system are essentially clearcuttings. In upland hardwood stands, for instance, Roach and Gingrich (1962) recommend cutting all stems larger than 2 inches d.b.h. Harvest cuttings under even-aged management are even more complete than commercial clearcuttings in that unmerchantable trees are killed. In some forest types, supplemental measures such as mistblowing or prescribed burning are also used to reduce or eliminate woody understories that hinder the establishment or growth of desired reproduction.

Increases in water yield from clearcutting have already been discussed. The evidence we will rely upon in this discussion is the 5.1-inch increase from the commercial-clearcut watershed on the Fernow Experimental Forest; 4 years later this increase had dropped to 2.2 inches.

To assess quantitatively the effects of even-aged management on water, a hypothetical situation may be useful for illustrative purposes. Take for example a 4,000-acre municipal watershed with an upland hardwood forest. The management objective is 24- to 28-inch sawtimber on an 80-year rotation. And the forester-in-charge plans to clearcut 500 acres every 10 years. The question is: what would be the increase in water yield for the 10-year period in respect to the clearcut area and to the entire watershed?

If, as the Fernow and Coweeta experience seems to indicate, the diminishing of increased yield over several years follows a straight line on semilog paper, and if we consider that the increase would be 5.1 inches the first year and about 0.5 inches after 10 years, annual increases from clearcutting 500 acres in terms of the increase from the total area of 4,000 acres would range from 0.64 to 0.06 inches (3.2 to 0.3 percent of an estimated average annual yield of 20 inches) (table 3).

Regularity in annual increases in water yield, by annual clearcutting of 50 acres, would produce, by the end of the 10-year cycle, an increased average annual water yield of 0.26 inches over the 4,000-acre watershed equivalent to a 1.3-percent increase or 28 million gallons annually. With adequate reservoir storage this would meet the annual water needs of 774 people (at 100 gallons per day), or irrigate 173 acres with 6 inches of water, or fill each year 3,146 swimming pools 10 x 30 x 4 feet in dimension. Thus, though the percent increase is small, the actual increase in volume of water is substantial. The size of the increase is noteworthy when we remember that it stems from a practice for which the main objective is increased timber income, not increased water yield.

However, the increase would be reduced to the extent that the forest bordering the clearcutting is drawing soil-moisture from it

Table 3.—*Predicted annual increase in water yield from clearcutting 500 acres of mature hardwoods per year*

Year	Increase in runoff			
	Clearcut area	Total area (4,000 acres)		
	Inches	*Inches*	*Millions of gallons*	*Percent*
1	5.1	0.64	69	3.2[1]
2	4.0	.50	54	2.5
3	3.0	.38	41	1.9
4	2.4	.30	33	1.5
5	1.8	.22	24	1.1
6	1.4	.18	19	.9
7	1.1	.14	15	.7
8	.8	.10	11	.5
9	.6	.08	8	.4
10	.5	.06	7	.3

[1] Based on average annual runoff of 20 inches.

and thereby reducing the possibilities of increasing water yield. The extent of this influence depends on the perimeter of the bordering forest, which in turn depends on the size of the areas clearcut. The smaller the areas cut, the greater their perimeter. In 1-acre cuttings, as much as 64 percent of the 500 acres clearcut would be influenced by a forest border of the largest trees. This would drop to 39 percent if the border contained a range of tree sizes. For 25-acre cuttings the percentages would drop to 15 and 9 percent, respectively.

The effect of thinnings on water yield may be similar to the effects of selection harvesting. Therefore, if 20 to 30 percent of the basal area of an even-aged stand were removed to increase the growth rate of the remainder, the first-year effect might be an increase in yield of about 1-inch, with no significant increase the second year.

All-Aged vs. Even-Aged Management

As we have noted, the effects of partial cuttings in extensive and intensive selection treatments are small, whereas partial cuttings through even-aged management can give substantial increases in water yield. Returning to our example of even-aged management, suppose equal volumes of timber had been removed in an extensive selection cut as in the clearcutting, what increase in yield would have been expected?

The clearcutting removed 86 percent of the timber volume for an increase of 5.1 inches or 138 thousand gallons per acre; the extensive selection removed 31 percent for 0.7 inch or 19 thousand gallons. Extensive selection on 2.77 acres would result in a volume of cut equal to 1 acre of clearcutting. It would provide an increased yield of 2.77 times 19 or 53 thousand gallons. This 53 thousand gallons is but 38 percent of the increased yield on 1 acre of clearcutting. Thus for purposes of water yield, for equal volumes of timber cut, extensive selection is 38 percent as effective as clearcutting. The Fernow intensive selection removed 20 percent of the timber volume for an increase of only 0.3 inch. This treatment applied to 4.3 acres would provide a timber cut equal to 1 acre of clearcutting; it would however yield an increase of only 35 thousand gallons; it may be considered 25 percent as efficient as clearcutting.

We can add to these estimates the observation that increases in flow were less persistent from the selection cuttings compared to the clearcutting. As a result, for equal volumes removed, a selection cutting would provide no more than one-fourth of the increase resulting from clearcutting. Obviously, removing a tree here and a tree there in a selection cutting will make more moisture available to the remaining vegetation and it will also provide more energy per unit of vegetation to consume the moisture. Therefore the effects on evapotranspiration and yield could only be small.

Fire, Insects, Diseases, and Hurricanes

The principles responsible for the effects of forest removal and partial cuttings on water yield pertain also to the effects of fire, insects, diseases, and hurricanes. Roughly, their effect on any one watershed would be related to the proportion of timber killed in the burned or infested area or the blowdown, and the proportion of that area to the watershed area.

Diseases are responsible for the greatest mortality of live sawtimber and growing stock in the Northeast, followed by other causes (weather, animals, suppression), insects, and fire. Estimated mortality for 1952 was as follows (U.S. Forest Service 1958):

Cause	*Growing stock (million cu. ft.)*	*Live sawtimber (million bd. ft.)*
Diseases	257	582
Other causes	231	323
Insects	31	77
Fire	12	17
	531	999

If confined to one area, these totals would be equivalent to perhaps 300,000 acres of forest destroyed. An estimated 8-inch increase in annual water yield over this supposedly plague-stricken area would be equivalent to an increase of 65 billion gallons of water. The fact that damages are scattered throughout the entire region and that in any one affected area mortality may be confined to a single disease or insect-ridden species tends to make water-yield effects small and very likely comparable to those from selection cuttings. Also, to a certain extent the damages occur from year to year over all areas and their effect is incorporated into what we might consider normal discharge for an area.

As we have mentioned, hot summer fires are necessary to get a significant kill of hardwoods: winter fires may do little damage. Generally, conditions necessary for hot summer fires are not common in the Northeast. For instance, on an average there are only 9 to 11 days annually in New Jersey and Pennsylvania when the burning index is 60 or more, a condition that accounts for more than half of the total acreage burned.[5]

Outside of the Coastal Plain, the Northeast is among the most fireproof regions in the country. The area burned in the period 1959-63 amounted to 1.3 percent of the protected state and private forest lands as compared to 3.3 percent for the six Central States, and 2.6 percent for the eight Southern States. Major fires in the Northeast have been associated with unusual periods of dryness and (outside of the Coastal Plain) unusual accumulations of slash or down timber.

The effects of diseases and insects on water yield are somewhat different from the effects of fire because they tend to be more selective. For instance, the effects of any one attack may be limited to one or two host species. Thus in forests composed of a number of different species, it is doubtful if a disease or insect attack can have a significant effect on water yield. Although chestnut blight reduced the productive capacity of the hardwood forest north of Maryland by 15 to 50 percent (Boyce 1938), it occurred in mixed stands and is a progressive disease, requiring 1 to 10 years to kill a tree, so that other species very likely were able to grow and maintain evapotranspiration rates. Water yield under these conditions would be little affected.

Spruce budworm, heartrots, and birch dieback are responsible for the greatest losses of timber in the Northeast. The 1910-20 epidemic of the budworm resulted in an estimated killing of about 8 billion board feet in New England, and a second outbreak occurred in the 1950's. Heartrot, which occurs in all tree species, accounts for one-third to one-half of the mortality from disease. Birch dieback since 1930 has destroyed much of the yellow and paper birch in New England. By 1958 almost 500 million board feet of sawtimber had been killed by this disease. Again, these infestations are active over a period of several years and over substantial areas and are therefore judged to have a negligible effect on water yield.

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[5] Unpublished reviews of the forest fire situation in Pennsylvania and New Jersey by Wayne Banks, 1964. Northeastern Forest Experiment Station, Upper Darby, Pa.

Among the damaging agents, catastrophic winds or fire are very likely the only events that would effectively increase water yield. The efficient forest fire protection organizations in the Northeastern States would seemingly reduce the chance for a holocaust. Hurricanes, like the one in 1938, which destroyed about half the merchantable timber in a swath 80 miles wide extending from Rhode Island and eastern Connecticut to the White Mountains (Barrett 1962), would doubtless tend to increase water yield to the extent that felled timber was killed. Eschner[6] has shown how extensive blowdown in the Adirondacks from a storm in 1950 interrupted a 39-year trend in which annual water yield from a protected forest watershed had gradually declined. Continuing mortality of storm-weakened trees during the next several years resulted in increased water yield.

REFORESTATION AND FOREST PROTECTION

The effect of regrowth after forest removal by clearcutting has already been discussed. Reforestation and the increasing of stand density through forest protection can similarly reduce water yield. For instance, planting 71 percent of an experimental watershed at Coshocton, Ohio, to locust and pine reduced annual water yield after 19 years by 5.3 inches (Brakensiek and Amerman 1964).

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[6] Eschner, Arthur R. FOREST PROTECTION AND STREAMFLOW FROM AN ADIRONDACK WATERSHED. Ph.D. Diss., Syracuse Univ. Coll. Forestry, Syracuse, N. Y. 1965.

Partially planting (47, 58, and 35 percent) three New York State watersheds to red pine and Norway spruce reduced November to April runoff, over a 23-year period, by 4.2, 5.1, and 6.8 inches. These dormant-season reductions were attributed largely to interception of snow by the evergreens. From 13 to 16 percent of the area was in open land and the remainder forested (Schneider and Ayer 1961). For the same area Muller[7] estimated that growing-season potential evapotranspiration on the Allegheny Plateau amounts to 2.6 inches more for hardwoods and 3.2 inches more for conifers than in open and overgrown lands. This was based on an estimated albedo of 0.19 for openland, 0.10 for second-growth hardwoods, and 0.08 for conifer plantations, and an estimate that one-half of the additional energy absorption by hardwoods and conifers is used in evapotranspiration. His water-balance calculations for all seasons indicated that replacement of agricultural land by conifer plantations results in an approximate 25-percent reduction in water yield.

Increased transpiration with growth of the stand suggests that if a watershed, consisting of forest land in various stages of growth and abandoned land reverting to forest, is protected from cutting and fire, transpiration over a period of years should increase and water yield should decrease. This was illustrated recently in a study by Eschner[6] to determine the effects of long-time protection on water yield in the Adirondack Forest Preserve.

Analyzing streamflow records of the 491-square-mile Sacandaga watershed, Eschner found that a slow one-directional change in land use and increase in forest cover was correlated with a decrease in annual, dormant-season, and April runoff over the 39-year period 1912-50. In 1912 the total forest stand density and the density of conifers were at a minimum after logging, insect attacks, and a series of fires. As forest density increased under protection, streamflow decreased: there was a reduction over the 39-year period of 7.7 inches or 23 percent of the 1912 annual runoff. Most of this, 5.2 inches, was a reduction in October-to-

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[7] Muller, Robert Albert. The EFFECTS OF FARM ABANDONMENT AND REFORESTATION ON WATER YIELD ON THE ALLEGHENY PLATEAU, NEW YORK. Ph.D. Diss., Syracuse Univ. Coll. Forestry, Syracuse, N. Y. 1962.

April runoff that may have been due to increased interception from the increasing amount of coniferous cover. An increase in the amount of soil-moisture recharge (because of increased transpiration the preceding growing season) also may have been a factor.

PRECAUTIONS AND SAFEGUARDS

The possibility of undesirable effects after treatment to increase water yields cannot be ignored. However, appreciable damage can be avoided if proper safeguards are taken. Most important, in all cutting and herbicidal treatments the forest floor should be disturbed as little as possible to maintain its characteristic high infiltration capacity. Roads and skidtrails should be kept to a minimum. In special cases where the area is kept in a low cover, the herbaceous vegetation can be relied upon to maintain high infiltration. These areas should not be grazed.

Flood Damages

Management of forested watersheds to increase water yield is not expected to produce damaging peak flows although this factor must be taken into consideration. On Coweeta watershed 17, where all trees were cut and left on the ground, a record first-year increase of 16 inches was obtained; however, no overland flow occurred and maximum peak-discharges were not significantly changed (Hoover 1944). Instantaneous peaks following the Fernow commercial clearcutting increased an average of 21 percent in the growing season and a negligible amount in the dormant season. Perhaps even more significant is that the larger percentage increases came with the smaller storms; the effect apparently diminishes as storm size increases. Also of importance, the major causative factor was antecedent soil moisture and not overland flow (Reinhart 1964b). Timber harvest on the Fernow by individual-tree selection had no determinable effect on peaks.

If only one-eighth of the Fernow watershed had been clearcut and regrowth permitted, as in our previous example of even-aged management, the increase in peak flows would very likely be of no practical significance.

Not only are the effects on the cutover watersheds minor; it is also probable that regionally only limited areas would be clearcut and they would be interspersed in areas largely uncut. Areas more intensively managed for water production, by methods like repeated spraying to keep vegetation at an erosion-prevention minimum, would be even more limited in size. Therefore we cannot conceive of a major effect on peak flows or possibilities of appreciable flood damages from water-yield management.

Where impervious surfaces are applied for the purpose of water harvesting, runoff will be most rapid. However, there appears to be no likelihood that large enough areas will be treated this way to cause a serious problem. Most of the water harvested would be channelled into reservoir or groundwater storage.

Water Quality

Erosion and sediment.—High water quality can be maintained in forest water-yield management by following rather simple, common-sense procedures. Studies at Coweeta and Fernow have shown, for instance, that clearcut areas with intact forest floor are not sources of overland flow (Reinhart 1964b) and do not erode (Hoover 1944). The qualifier here, of course, is the phrase "with intact forest floors". What is surprising is the considerable extent of forest floor that may remain intact even after clearcutting.

The forester's principal concern, then, is to see that the forest floor is subjected to minimum disturbance. How? By careful location and construction of truckroads and skidroads and necessary maintenance. A haphazardly built transport system may disturb as much as 20 percent of the surface: a well-planned system need not occupy more than 10 percent of the land area (Haussman 1960). Clearcutting, as compared to selection cutting, would require perhaps more careful attention to erosion control to offset the greater soil compaction associated with the greater volume of timber removed.

Basic safeguards to protect water quality have been set forth by Trimble (1959):

- Locate roads and trails away from stream courses except where a stream crossing cannot be avoided. The distance between stream and road should be 50 feet plus 4 feet for each 1 percent of slope between them. Thus on a 20-percent slope the road should be kept about 130 feet away from the stream.
- Keep logging operations away from the stream to prevent soil disturbance near the stream and to keep slash from plugging the channel and causing bank-cutting.
- Truckroads should cross all water courses, even ephemeral ones, on closed culverts or bridges.
- Except for very short stretches, the maximum grade on truckroads and heavily used skidtrails should be less than 10 percent.
- For adequate road drainage the intervals in feet between cross drainages can be calculated from 1,000/percentage of grade.
- As far as possible, build roads and skidtrails in dry weather. Wet-weather operations increase erosion.
- The sooner the logging job is finished, the shorter will be the period of greatest erosion hazard.
- After the logging job is finished, remove temporary bridges and open-top culverts and seed problem areas with grasses.
- Close supervision is required to insure the safeguarding of water quality.

Herbicides.—Arguments in recent years over the use of pesticides are known to all. Generally herbicides are much less toxic to humans and animals than insecticides. With many herbicides, objectionable taste and odor levels are much lower than levels of toxicity. Even so, wherever domestic water supplies are involved, herbicides must be applied with caution; and odor should be taken as a warning of possible toxicity. However, in three pertinent studies, little or no contamination was reported.

Streamside vegetation on two small headwater streams at Newfoundland, N. J., and two near State College, Pa., were sprayed with 2,4,5-T in an oil-water emulsion and 2,4,5-T diluted in water only (Reigner et al. 1964). In each watershed the operator mist-sprayed swaths 20 feet each side of the stream for a distance of about 1,000 feet. Water samples were taken below the treated stretch and 1 mile downstream immediately after treatment, 4 hours after treatment, at daily intervals, after the first rainstorm following treatment, and after the first storm of 1.0 inch precipitation or more.

Contamination was found in samples taken below the treated area within 4 hours after treatment, and in one watershed after the first rain of 1 inch or more. Concentrations of the herbicide in the samples were estimated to be 40 p.p.b. (parts per billion) immediately after spraying, 20 p.p.b. 4 hours later, and 10 to 20 p.p.b. after the first large storm (1,000 p.p.b. are considered toxic). No contamination was found downstream. Since very little contamination occurred it was concluded that with normal precautions phenoxy herbicides can be used on municipal watersheds.

At the Fernow Experimental Forest in West Virginia, basal spraying, stump treatments, and foliage spraying with 2,4,5-T during the course of a clearcutting operation resulted in no detectable contamination of streamflow (Reinhart 1965).

In southern California, spraying vegetation in a strip 100 to 400 feet wide along 1.3 miles of canyon bottom with a mixture of 2,4-D and of 2,4,5-T resulted in no herbicide contamination of water samples taken within a few days after spraying. Small traces of oil used in the spray mixture, ranging from 2 to 30 parts per million, were detected (Rowe 1963).

DISCUSSION AND CONCLUSIONS

To date no one in the Northeast has taken advantage of the possibilities for increasing water yield by cutting trees. The cities of Baltimore and Newark have been interested sufficiently to institute research programs on their own watersheds (Lull 1960). Interest of other Northeastern municipalities is attested to by the recent Municipal Watershed Management Symposium at Amherst, Mass. (Noyes 1967). Outside this region, the major action program for water-yield increase is in Arizona (Arizona Water Resources Committee 1959), where climatic conditions are not nearly as suitable for increasing water yield as in the Northeast.

An efficient program for increasing water yield depends on provision of sufficient reservoir storage to contain the increases. In some cases, increase in summer yield may be necessary because of insufficient reservoir storage for winter and spring runoff. The decision about the necessity of forest water-yield management under these circumstances will depend on alternative costs of increasing reservoir storage.

Before anyone embarks on a program of forest water-yield management, we suggest a degree of conservatism. First, alternative possibilities for increasing water yield—and their costs—should be investigated. Second, the feasibility of forest water-yield management should be judged in light of the physical geography of the area concerned, and forest watershed managers of some experience should be consulted. No two watersheds are alike, and though the forces that govern delivery of streamflow are the same at all watersheds, the physical conditions under which these forces operate may be quite different.

With these qualifications in mind, the following conclusions are offered:

- Removal of all vegetation on a well-stocked forested watershed in the Northeast will increase annual water yield the first year after treatment by about 4 to 12 inches.

- Water-yield increases from forest removal will probably appear mostly in the late summer months.

- Costs of forest removal range from $2 to $10 per acre for controlled burning, $5 to $25 for herbicidal treatment, and $100 to $200 for clearcutting. A combination of a commercial clearcutting and herbicidal treatment may cost in the neighborhood of $30 per acre.

- Regrowth 5 years after forest removal can lower the water-yield increase by two-thirds, and after 10 years most of the increase will have disappeared.

- Foliar sprays, annually or every other year, are probably the most efficient way of maintaining high increased yields. Annual or biennial spraying will be necessary until most of the vegetation is killed. The spraying will cost $5 to $25 per acre.
- Maintenance of high increased yields must be accompanied by encouragement and maintenance of a protective ground cover.
- Partial cutting under all-aged management can have only a minor effect on water yield.
- Partial cutting under even-aged management as done in a sustained-timber-yield program can yield a small percentage increase in annual water yield but a somewhat substantial increase in terms of water volume. The magnitude of the increase will depend on the proportion of the watershed area cut, the size of individual clearings, and the condition (and water use) of the forest stand before cutting.
- Thinnings may have only a negligible effect on water yield.
- Planting abandoned agricultural land to conifers can in time reduce annual water yield as much as 25 percent where snowfall is abundant.
- Long-term protection of forest land from fire and cutting will tend to reduce annual water yield. The reduction will depend on how thoroughly the original stand occupied the site.
- Clearcutting upland areas of a forested watershed during a drought will not provide relief until after rainfall or snowmelt has recharged the soil. Clearcutting riparian areas can increase water yields.
- Below- or above-normal annual precipitation after forest removal may not have a pronounced effect on water-yield increases.
- In general, damage caused by fire, insects, and diseases will have a negligible effect on water yield.
- Forest cover along reservoir shorelines can use an estimated 1 to 6 area-inches more water annually than upland forest cover.

To reduce these losses, the shoreline forest should be cut back to a line 10 to 15 feet above the water table.

- Waterproofing the soil surface can produce water yields equivalent to about 90 percent of annual rainfall at costs competitive with other methods of increasing water supplies.
- Management of forested watersheds to increase water yield is not expected to produce peak flows of damaging consequence.
- High water quality can be maintained in forest water-yield management by following basic safeguards in location, use, and maintenance of logging roads and skidtrails. How restrictive these safeguards must be depends upon local conditions.
- Little contamination has been reported from limited experimental use of herbicides in treatments to increase water yield.

These conclusions provide a basis for an action program to increase water yields. In considering the possibilities, the watershed manager should study carefully:

1. Nearby streamflow records of the U.S. Geological Survey that can provide some understanding of annual and seasonal discharges that may be expected locally from forested watersheds, and their relation to variation in annual and seasonal precipitation.

2. Regional atlases that depict mean precipitation, streamflow, and evapotranspiration (Knox and Nordensen 1955; Schneider et al. 1965).

3. Regional studies of streamflow, its variation, and factors that influence it (Sopper and Lull 1965; Lull and Sopper 1966a, 1966b).

4. Results of forest-watershed-management research as to the effects of forest cutting on water yield (Reinhart et al. 1963; Hewlett and Hibbert 1961).

Additional information can be obtained in the Northeast at the following locations where forest watershed research is now under way:

Watershed Management Research Project
Northeastern Forest Experiment Station
Durham, New Hampshire 03824

Watershed Management Research Project
Northeastern Forest Experiment Station
Upper Darby, Pennsylvania 19082

Watershed Management Research Project
Northeastern Forest Experiment Station
Parsons, West Virginia 26287

New York State University College of Forestry
at Syracuse University
Syracuse, New York 13210

School of Forest Resources
The Pennsylvania State University
University Park, Pennsylvania 16802

If time permits, the watershed manager may wish to calibrate and clearcut small experimental watersheds (20 to 60 acres) to determine for his area the maximum possibilities for increasing yield. Such a program requires a minimum of 10 years, the construction of two or more gaging stations (for construction details see Reinhart and Pierce 1964), and the operation of a climatic station. Research of this kind is now under way at Newark, N.J., and Baltimore, Md., watersheds in cooperation with the Northeastern Forest Experiment Station (Lull 1960). Shorter-term soil-moisture studies of the kind recently reported by Mader et al. (1967) and Hunt (1967) for Boston's Quabbin Reservoir watershed may give an indication of treatment results.

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APPENDIX
A

Clearcutting Costs

Costs and related information for clearcutting oak-hickory forest at the Coweeta Hydrologic Laboratory in 1962-63 were as shown in the table below.

Watershed area, slope, and forest cover

Watershed No.	Area	Average slope	Forest cover	
			Basal area*	Stems
	Acres	*Percent*	*Sq. ft./acre*	*No./acre*
13	40	26	74	2,364
28	86	31	—	—
37	108	27	118	1,637

Cost of Treatment

Watershed No.	Labor	Cost in dollars per acre		
		Labor	Operation**	Total
	Man-days per acre			
13	10.3	$108	$20	$128
28	8.8	94	18	112
37	8.8	—	—	—

* Basal area in stems 1 inch and larger.

** Operation costs include vehicle mileage, repairs, and 100 percent depreciation of power saws, axes, etc.

Hourly wage rates changed periodically but were about $1.87 for work leaders, $1.70 for power-tool operators, and $1.35 for laborers. The most efficient crew organization consisted of a foreman, 3 crew leaders, and about 8 two-man power-saw teams using 5-horsepower direct-drive chain saws. Chain-saw crews were more effective than combined chain-saw and ax crews. Clearcutting residual material after a commercial clearcutting and timber-sale operation on watershed 28 required 2.45 man-days per acre, a 70 percent reduction in labor costs over clearcutting.[3]

On the Pisgah National Forest in western North Carolina, an area clearcut was given an intensive cleaning in the winter of 1959-60. In cleaning, all woody stems except selected crop trees were cut. Before cleaning, the 11-year-old stand averaged 3,214 saplings per acre of stems over 4.5 feet tall; after cleaning, spacing was just under 9 x 9 feet. The mountain slopes averaged 42 percent in steepness and ranged from 18 to 72 percent.

Cleaning time averaged 7.3 man-days per acre for two 3-man crews equipped with one chain saw and two axes per crew. The men were experienced browse cutters employed by the North Carolina Wildlife Resources Commission. The cleaning required as few as 6.1 man-days per acre and as many as 11.1 man-days. Slope steepness, and especially shrubby growth *(Kalmia latifolia* and *Rhododendron maximum)* and vines *(Vitis* spp. and *Smilax* spp.) increased the cleaning time considerably.[8]

Cutting noncommercial material in 1949 after a commercial clearcutting of 70 acres on the Pisgah National Forest cost $43 per acre (Ripley and Campbell 1960).

In 1964 a 50-acre tract was clearcut on the upper Long Branch drainage of the Bent Creek Experimental Forest. The area was very steep with slopes generally over 50 percent. About 400,000 board feet of overmature timber, including pulpwod, was removed by commercial loggers. All remaining trees under pulpwood size and over 4.5 feet tall were cut by a contractor for $35 per acre. About 8 acres contained dense stands of laurel and rhododendron, which increased the cost somewhat. On similar areas without laurel and rhododendron a complete removal job will cost about $25.[8]

APPENDIX

B

Costs of Frilling and Tree Injection

Costs of frilling and poisoning hardwoods at the Duke Forest in North Carolina in relation to tree diameters were as follows:

Inches d.b.h.

4	6	8	10	12	14	16	18
4.8¢	5.8¢	6.9¢	8.0¢	9.0¢	10.0¢	11.1¢	12.2¢

Costs were based on an hourly wage of $0.95 and $0.22 per pound for ammate (Carvell 1956). In an even-aged stand of 500 trees per acre with an average d.b.h. of 6 inches, this treatment would cost $29.00 per acre; for 240 ten-inch trees, $19.20. Cost of treatment per inch of diameter ranges from $0.012 for the 4-inch trees to $0.007 for the 12-inch trees.

A number of studies show that frilling and poisoning hardwood culls with 2,4,5-T costs from $0.005 to $0.011 per diameter-inch. In Maryland, Little and Mohr (1956) found that treatment of 385 trees per acre with an average diameter of 6 inches cost $13 to $15 (0.006 per diameter-inch). In Ohio, Ryker and Minckler (1962) reported that their treatment cost $0.011 per tree diameter-inch. Peevy (1960) reported a cost of $0.005 for poisoning southern weed trees. MacConnell and Babeu (1964) reported per diameter-inch costs of $0.007 for frilling hardwoods in Massachusetts and costs of $0.009 for killing 4- to 12-inch trees and $0.016 for killing 13- to 25-inch trees.

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[8] Communication of March 4, 1966, from Charles E. McGee, project leader, U. S. Forest Service, Asheville, N. C.

At the Fernow Experimental Forest in West Virginia, Yawney (1961) found that frilling and ammate treatment of 6 to 15 cull trees per acre cost $1.32 to $3.61, with an average cost per inch of tree diameter of $0.017. This was based on a labor cost of $1.20 per hour and ammate at $0.24 per pound. An average of 108 tree-diameter inches was treated per man-hour and 44 inches treated per pound of ammate.

Tree injection costs are somewhat lower. Peevy (1960) reported a cost of $0.003 per diameter-inch for tree injection of southern weed trees, and MacConnell and Baben (1964) treated Massachusetts hardwoods for $0.007, and reported killing costs of $0.007 for 4- to 12-inch trees and $0.014 for 13- to 25-inch trees using the amine form of 2,4,5-T. In 1966 Little and Cramner found that labor ($2 per hour) and chemical costs for treating a thousand diameter-inches with six commonly-used chemicals ranged from $4.89 to $6.31.[9]

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[9] Unpublished data, Northeastern Forest Experiment Station.

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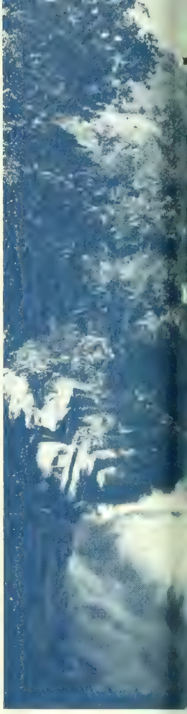

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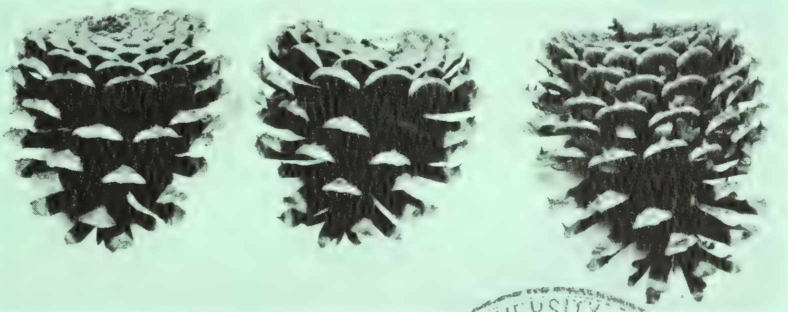
NATURAL HYBRIDS among Pond, Loblolly, and Pitch Pines



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U. S. FOREST SERVICE RESEARCH PAPER NE-67
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

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NATURAL HYBRIDS

among Pond, Loblolly, and Pitch Pines

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INTRODUCTION

NATURAL hybrids or intergrades between pond and loblolly pines *(Pinus serotina* X *taeda)* occur in Delaware and Maryland, and hybrids or intergrades between pitch and pond pines *(P. rigida* X *serotina)* are found in New Jersey, Maryland, and Delaware. Hybrids between pitch and loblolly pines *(P. rigida* X *taeda)* are somewhat rare, but are known in New Jersey and Maryland. This paper describes the characteristics of the intergrades and of the parent species, and discusses the value of distinguishing intergrades and species in forestry practice.

Several natural interspecific hybrids have been recorded among closely related species of pines. And additional natural hybrids may be expected because so many artificial crosses have been made. However, interspecific hybridization in nature is the exception, not the rule. For, if crossing between two species were common, the populations of offspring would be so variable or so intermediate that taxonomists could distinguish only a single species.

Differences in geographic distribution or in time of pollination usually serve as a barrier to the crossing of closely related species of pines. For example, natural hybrids between jack pine *(Pinus banksiana* Lamb.) of the northeastern United States and Canada and lodgepole pine *(P. contorta* Dougl.) of western North America were observed by Moss *(20)* in central and northwestern Alberta, where the ranges of the parent species overlap. However, geographic isolation has prevented extensive crossing.

Differences in the usual time in pollination have limited the amount of hybridization between longleaf pine *(P. palustris* Mill.) and loblolly pine *(P. taeda* L.) in the southeastern United

States. Hybrids between these two species were reported first from Louisiana by Chapman *(1)*; afterwards they were found in North Carolina and Texas, and they have been produced artificially. Similarly, loblolly pine sheds its pollen 3 to 4 weeks before pond pine, according to Dorman and Barber *(5)*; thus natural hybridization is limited between these species.

REVIEW OF LITERATURE

Silvical characteristics, including range maps and notes on hybrids, have been summarized for the three species: pond pine *(Pinus serotina* Michx.) and loblolly pine *(P. taeda* L.) by Wenger *(25, 26)*, pitch pine *(P. rigida* Mill.) by S. Little *(15)*. Wenger reported that natural hybrids occurred between the first two where they were closely associated, and that artificial hybrids are growing at the Westvaco Experimental Forest near Georgetown, South Carolina.

These three species can be crossed readily. In his review of hybridization of the southern pines, Critchfield *(4)* reported many successful artificial combinations, though natural hybridization is not conspicuous.

Pitch Pine and Pond Pine

Intergrades between pitch pine and pond pine have long been known, and have affected their separation into distinct species. Sargent *(21)* and Sudworth *(23)* regarded the two as varieties of the same species, although previously both authors had separated them into two species in references published in 1897. As early as 1838, Loudon associated the two, but used the name for pond pine as a species: *Pinus (r.) serotina* Michx. ex Loud. (Arb. Frut. Brit. 4: 2242, figs. 2127-2130. 1838). Pond pine was later reduced to a variety, *P. rigida* var. *serotina* (Michx.) Loud. ex Hoopes (Book Evergreens 120. 1868), as noted by E. L. Little *(11)*.

Clausen *(2)* studied taxonomic relationships of pitch and pond pines after collecting intermediate specimens at West Cape May, New Jersey. Long *(17)* first recorded pond pine in New Jersey in 1909. Regarding pond pine as a subspecies, Clausen *(2,* p. 126) made the combination *P. rigida* subsp. *serotina* (Michx.) Clausen. After examining specimens collected from Massachusetts to Florida, Clausen concluded that the length of leaves was the best basis for separating the two populations of pitch and pond pines, that this character exhibited a geographical gradient, and that a length of leaves of 15 cm. or more, from southern New Jersey southward, might be considered the arbitrary dividing line. He excluded geographic range as a basis for specific segregation, ignored length of leaf sheaths as repetition of leaf length, and found prickles on cone scales to be tremendously variable.

In Delaware, where both pitch and pond pines occur, Taber *(24)* described and illustrated the distinguishing characteristics of both. Compared with pitch pine, pond pine had longer needles; shorter, flatter cones; shiny, usually weak-prickled tips of cone scales, and somewhat longer buds.

In North Carolina, Coker and Totten *(3)* were "quite unable to accept" the disposition of pond pine as a variety of pitch pine. They cited differences not only in leaves, cones, and stature, but also in soil requirements and distribution. The regional floras of Fernald *(7)* and Gleason *(8)* also maintained the two as separate species.

In connection with soil requirements, it should be noted that in the Northeast, especially in New Jersey, pitch pine grows on sites commonly considered restricted to pond pine in the Southeast —poorly or very poorly drained sands (such as Leon and St. Johns soils) and peats of the Coastal Plain. Of course pitch pine is also common on ridge sites in both sections, and in the Northeast on sandy or gravelly plains of outwash or other origin.

When revising the Forest Service Check List *(23)*, the senior author retained pond pine as a variety in a preliminary mimeographed edition (1944). Southeastern foresters protested and demonstrated the differences. Accordingly, pond pine was accepted as a species in the 1953 Check List *(13)*.

Pitch Pine and Loblolly Pine

Natural hybrids between pitch and loblolly pines have been relatively unknown because the ranges of the two scarcely meet. However, they do occur.

Artificial hybrids between pitch and loblolly pines were made at the Institute of Forest Genetics, Placerville, California, as early as 1933 *(6)*. More recently this hybrid has been mass-produced in Korea (where 11,000 to 30,000 pollination bags have been mounted annually), mainly because the hybrids are faster growing than pitch pine and hardier than loblolly pine *(9, 10)*. In test plantings in Maryland and Illinois, the hybrids have had slower growth and less desirable form than typical loblolly stems *(16, 18)*.

FIELD WORK

Natural gradations among these three species have been observed, especially by the second author in his field work over a period of years. For additional comparisons, herbarium specimens were collected by the authors on field trips in September 1959 and in October 1961. On these trips the following foresters of State forestry departments assisted: Charles W. Holsworth in southern New Jersey, William S. Taber in Delaware, and John J. Mohr in eastern Maryland. More specimens were collected in November 1965 at the Beltsville Experimental Forest, U. S. Forest Service, in northern Prince Georges County, Maryland (about 10 miles northeast of Washington, D. C.). Many intermediate trees occur in the Beltsville area.

The herbarium specimens were collected from trees of the three species as well as from trees with the intermediate characteristics of hybrids or intergrades. Representative specimens have been deposited in the herbaria of the U. S. Forest Service and U. S. National Museum at Washington, D. C., Rutgers University, the University of Maryland, and the Institute of Forest Genetics, Placerville, California.

COMPARATIVE CHARACTERS

The main contrasting characters of the three species and their natural hybrids or intergrades are summarized in table 1, which may serve to verify hybrid trees and specimens. The characters of the listed hybrids were taken from specimens that were about equally intermediate between the two species, or that were probably first-generation offspring.

Of course, many of the intergrades do not have equally intermediate characteristics between the two species, but are more like one of the parent species. Such trees may result from subsequent backcrossing (introgression). Even though many of the trees examined fell in this category, their characteristics could not be included in table 1.

Taxonomic characters included in table 1 are limited to those in which two or three species differ, while those common to all parents and progeny are omitted. For the hybrids, characters are indicated by I if intermediate or by the first letter of the epithet of one parent if like that parent. The characters of each hybrid are summarized at the bottom of the table. Thus, the pitch-pond hybrid is intermediate in 10 characters and like pond pine in 2. The pond-loblolly hybrid is like pond pine in 3, like loblolly pine in 3, and intermediate in 15. The pitch-loblolly hybrid is like pitch pine in 8 characters, like loblolly pine in 1, and intermediate in 7. In Mississippi, Mergen et al. *(19)* found that for some characters, loblolly-shortleaf pine hybrids occupy a generally intermediate position betwen the two parent species.

Of course, as table 1 illustrates, pitch pine and pond pine are closely related and have more characters in common with each other than with loblolly pine.

Habit

Typical mature trees of loblolly pine are fairly large and have relatively straight trunks. Many stems, especially of the younger ones, have long sweeps; a typical, pronounced one is shown in figure 1. Dead branches are shed rather rapidly. Typical growth of loblolly pine is appreciably more rapid than the growth of pitch or pond pine on the same site.

Mature stems of pitch pine are of medium size or relatively small. Their crowns are often irregular; the branches are often gnarled and twisted, especially on open-grown trees that have been subjected to adverse environmental conditions. Suppressed trees, stems damaged by past wildfires, or those released by heavy cuttings usually have drooping, slender branches along the lower boles. The boles of large, stand-grown trees may appear fairly clear; but dead branches, being more resinous, are retained longer

Table 1.—*Comparison of contrasting characters of the three pine species and their natural hybrids*

Character	*Pinus rigida* (pitch pine)	*Pinus rigida* X *serotina* (pitch-pond hybrid pine)	*Pinus serotina* (pond pine)	*Pinus serotina* X *taeda* (pond-loblolly hybrid pine)	*Pinus taeda* (loblolly pine)	*Pinus rigida* X *taeda* (pitch-loblolly hybrid pine)
Trunk:						
Leaves on short twigs	Present.	Present.	Present.	Usually absent (I).	Absent.	Usually absent (I).
Buds	Usually resinous.	Usually resinous.	Usually resinous.	Usually resinous (S).	Usually non-resinous, shiny.	Resinous (R).
Leaves:						
Length	6-14 cm.	10-17 cm. (I).	11-20 cm.	12-21 cm.	12-22 cm.	10-19 cm. (I).
Width	1.1-1.6 mm.	1.4-1.6 mm. (I).	1.6-1.8 mm.	1.4-1.6 mm. (I).	1.1-1.3 mm.	1.1-1.5 mm.
Stiffness	Slightly stiff.	Slightly stiff.	Slightly stiff.	Flexible to slightly stiff (I).	Flexible.	Slightly stiff (R).
Marginal teeth	Fine.	Fine to stout (I).	Stout.	Fine (T).	Fine.	Fine.
Resin canals	2-6 (11), small.	3-9, mostly small.	3-9, mostly small.	4-5, mostly small (I).	2-4 (6), large and small.	2 large and 0-2 small (I).
Cones:						
Length	4-7 cm.	4.5-6.5 cm. (I).	4.5-6 cm.	7-9 cm. (I).	7-11 cm.	5-6 cm. (R).
Width closed	2.5-3.5 cm.	3.5 cm. (I).	4-5 cm.	3.5-4.5 cm. (I).	3.5 cm.	3.2-3.5 cm.
Width open	4.5-5.5 cm.	5-6 cm. (I).	5.6-7 cm.	5.5-6 cm.	6-7.5 cm.	4.5-6 cm. (I).
Shape closed	Narrowly ovoid.	Ovoid (I).	Ovoid to subglobose.	Conic or narrowly ovoid (I).	Conic.	Conic (T).
Shape open	Ovoid, mostly longer than broad, broadest below middle, flattened at base.	Ovoid, almost as broad as long, flat at base (I).	Nearly hemispherical, broader than long, broadest at flat base formed by reflexed scales.	Ovoid, broadest below middle, flattened at base (I).	Ovoid, broadest below middle, not flat at base.	Ovoid, flattened at base (R).

Dehiscence	Early or late.	Early.	Late (serotinous) to early.	Early to late (I).	Early.	Early.
Persistence	Persistent.	Persistent.	Persistent.	Partly persistent (I).	Usually deciduous.	Persistent (R).
Phyllotaxy	Normal.	Intermediate (I)	High order, many scales.	Intermediate (I).	Normal.	Normal.
Cone scales:						
Width	7-10 mm.	6-10 mm.	6-10 mm.	9-13 mm. (I).	12-15 mm.	8-13 mm. (I).
Keel	Prominent.	Weak on basal scales (S).	Weak on basal scales.	Weak on basal scales (S).	Prominent.	Prominent.
Prickle	About 2 mm. long, small, slender, sharp, persistent.	About 1-2 mm. long, small, slender, mostly persistent (I).	About 1 mm. long, or less, small, slender, weak, often deciduous.	About 2-3 mm. long, or less, small, slender, sharp, persistent (I).	About 2-3 mm. long, including broad umbo, large, stout, persistent.	About 2 mm. long, small, slender, sharp, persistent (R).
Prickle on basal scales	Almost same size.	Smaller (S).	Smaller.	Smaller (S).	Almost same size.	Almost same size.
Color of apophysis	Tawny yellow, slightly shiny or dull.	Tawny yellow, slightly shiny or dull.	Tawny yellow, slightly shiny.	Tawny yellow, dull (I).	Nut brown, dull.	Tawny yellow, slightly shiny or dull (R).
Seed:						
Length with wing	15-21 mm.	19-24 mm.	21-24 mm.	24-27 mm. (I).	27-28 mm.	21-22 mm. (I).
Length of body	4-5 mm.	5 mm.	5 mm.	6-7 mm. (T).	6-7 mm.	4.5-6 mm. (I).
Shape of body	3-angled.	3-angled.	3-angled.	Rhomboid or ovoid (T).	Rhomboid or ovoid.	3-angled (R).
Summary	—	10 I, 2 S.	—	3 S, 15 I, 3 T.	—	8 R, 7 I, 1 T.

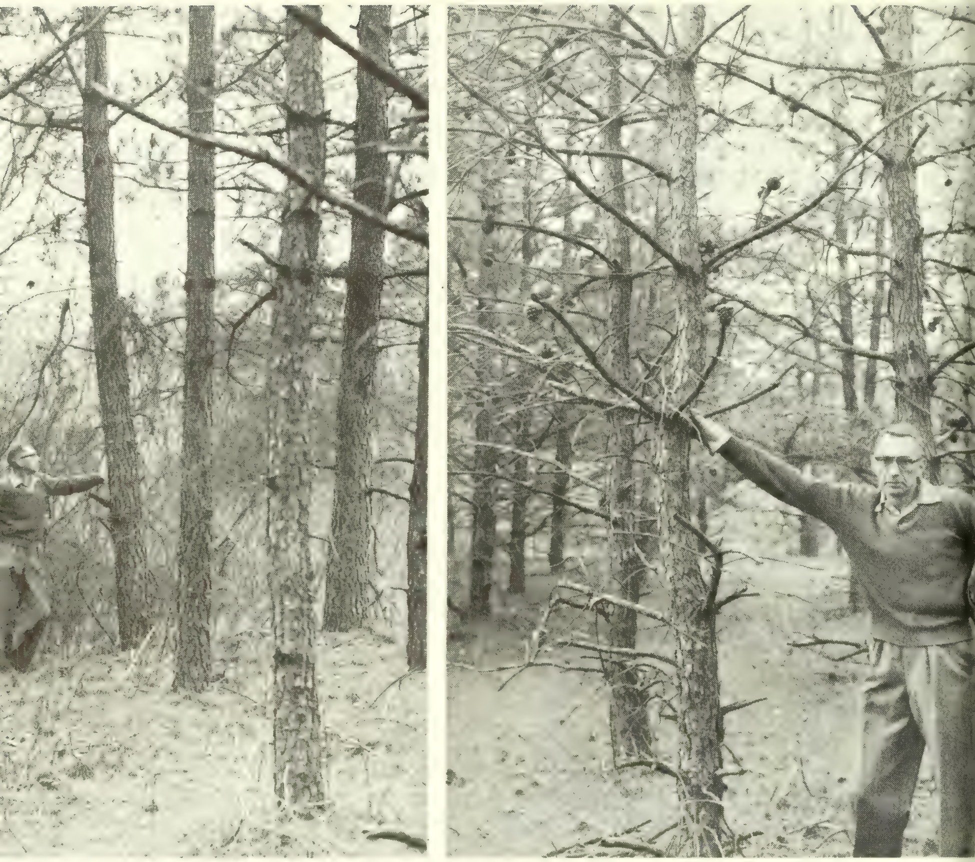

Figure 1.—Comparative size and form of loblolly pines (left) and of pitch-loblolly hybrids (right) 17 years after planting. Note the sweep, relatively clear length, and large size of the loblolly pine stem by the man in the left photograph, in contrast to the short crooks, dead branches, and cones on the hybrid stem in the right foreground.

than in loblolly (fig. 1). Usually, too, small clusters of needle fascicles still occur at many of the lower nodes or at the base.

Pond pine may be somewhat intermediate in size, but in nearly all respects resembles pitch pine more closely than loblolly pine. Mature pond pines tend to have open crowns with stout branches, often drooping at the ends.

Stems of both pitch pine and pond pine are typically crooked and irregular in form. The crooks in young trees differ appreciably from the long sweep common in loblolly; the crooks in pitch and pond pine are short and irregular (fig. 1). Many, of course, are eventually overgrown so that—unless site, environment, past history, or treatment are too adverse—older trees of both species may have relatively straight stems.

Vegetative Reproduction

Pitch pine and pond pine both have the vigorous vegetative capacity of sprouting, especially after fires. These two species and their hybrid have characteristic short twigs and leaves along the trunk. Loblolly pine and some of its hybrids with the other two species lack these features.

Leaves or Needles

Pitch pine is distinguished from pond pine partly by the shorter leaves, but their hybrid is intermediate. Pond pine, loblolly pine, and their hybrid have long leaves. The leaves of pond pine measure slightly wider than those of the other two species; however, the hybrids are intermediate.

Pitch pine, pond pine, and their hybrids have slightly stiff or rigid leaves, although loblolly pine and some of its hybrids have flexible leaves. The difference in flexibility can be distinguished by touch: clusters of needles at the end of a branch or terminal of pitch pine or pond pine tend to prick the skin when a hand is held against them, whereas needles of loblolly pine bend and feel soft against the palm.

Typical foliage of loblolly pine is also lighter in color than that of the other two species.

Needle Anatomy

Pitch pine, pond pine, and their hybrid are not distinguishable in needle anatomy according to microscopic examination of freehand cross-sections. All are characterized by three usually small medial resin canals in the angles, and usually 1 to 6 additional small, medial, or medial and internal canals. Loblolly pine differs slightly in having usually fewer, but larger resin canals (mostly more than 40 microns in diameter) 2 or 3 medial in angles, and sometimes more.

Cones

Cone characters are basic in classification within the genus *Pinus.* Representative cones of these three species and their three hybrids are shown in figure 2. Pond pine is recognized by its distinctive broad egg-shaped to nearly spherical cone, which remains attached for several years, usually closed *(26).* The numerous closed cones, weathering to gray on the older branches, resemble eggs or balls, and form an important characteristic in distinguishing this species. Even the specific epithet, meaning late, refers to the cone, which typically remains closed until opened by a fire to release the seeds.

The other two species differ from pond pine in cone characters. Loblolly pine has longer cones, and pitch pine has narrower cones than either loblolly or pond pine. The open cone of pond pine is nearly hemispherical, broader than long, and broadest at the flat base formed by reflexed scales. Open cones of the other two species are usually longer than broad, and widest below the middle. The broad cone of pond pine has a high order of phyllotaxy in the middle portion, that is an efficient arrangement with numerous scales.

The mature cone of loblolly pine is dull nut-brown in color at the ends or apophyses of cone scales, while the color in the other species is tawny, often slightly shiny, yellow. The prickle on cone scales of loblolly pine is unusually large and stout; the prickle of pond pine is small, slender, weak, and often deciduous, especially on the basal scales. In pitch pine the prickle is intermediate between the other two species.

Time of cone opening or dehiscence is early or soon after maturity in loblolly pine and its hybrids, but variable in the other two species. Pond pine trees growing in swamps usually have closed cones, although some on dry sites have cones that open, either soon after maturing or over a period of several years. These variations and similar ones in pitch pine apparently represent local or geographical adaptations to differences in frequency of fires.

Cone production and retention also differ among the three species. Both pitch pine and pond pine produce cones at an earlier

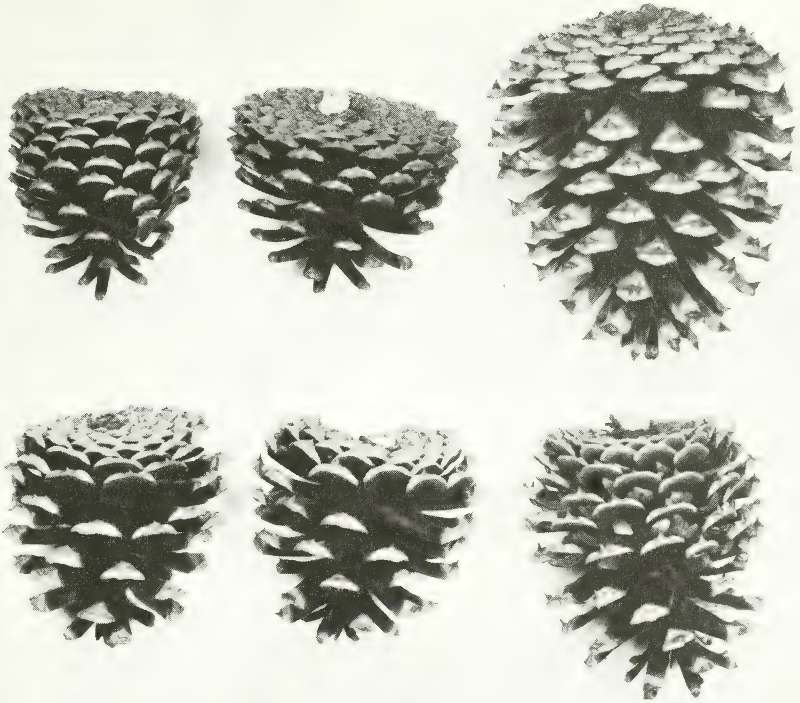

Figure 2. — Cones compared, approximately one-half natural size. Top row: pitch pine, pond pine, loblolly pine. Bottom row: pitch pine X pond pine, pitch pine X loblolly pine, pond pine X loblolly pine.

age than loblolly. Pitch pine may bear mature cones on 3-year-old sprouts or 4-year-old seedlings, but usual cone production on open-grown seedlings does not begin until stems are 8 to 12 years old *(15)*. Pond pine apparently begins cone production at about the same age *(26)*. Although individual trees of loblolly pine less than 10 years old occasionally produce cones, appreciable cone production does not begin until much later *(25)*. Thus an appreciable number of cones on sapling-size stems is characteristic of pitch or pond pine, but not of loblolly. Furthermore, loblolly usually drops its cones within a year or two after they mature, so that large numbers of old cones are characteristic of pitch and pond pines, but not of loblolly.

Cone characters of the hybrids and their offspring are gradational between species (fig. 2). Some trees may have cones similar in size and shape to loblolly pine, but are like pond pine in type of cone prickles, retention of old cones, and early and abundant fruiting. Possibly because of backcrossing, many of the gradational trees have nearly all the features of one species, with only one or two characteristics of the second species.

BOTANICAL DESCRIPTIONS

The three natural hybrids described below are designated by formulas that will include all recognizable natural and artificial hybrids between the same two parent species *(14)*. Though Latin binary names have been given to most natural interspecific tree hybrids in the past, further use of binomials seems neither useful nor necessary. Most workers in forest-tree-improvement programs in the United States prefer the formulas and oppose binomials for hybrids. Any particular variations of these crosses produced in quantity may be given English variety (cultivar) names as needed and under the International Code of Nomenclature for Cultivated Plants.

Pinus rigida X serotina (Pitch Pine X Pond Pine)

Pinus rigida X *serotina*, pitch pine X pond pine, or pitch-pond hybrid pine. Natural hybrid tree with leaves and cones intermediate between *Pinus rigida* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 10. 1768), pitch pine, and *P. serotina* Michx. (Fl. Bor.-Amer. 2:205. 1803), pond pine. Medium-sized tree 9 m. (30 ft.) or more in height and 20 cm. (8 in.) or more in trunk diameter. Bark brownish gray, rough, thick, furrowed into long scaly plates. Trunk bearing leaves on short twigs. Buds cyclindric, acute to acuminate, reddish brown, resinous.

Leaves 3 in fascicle, slightly stiff, 10-17 cm. long, 1.4-1.6 mm. wide, serrulate, green; whitish stomatal rows 13-18 on dorsal surface and 5-11 on each ventral surface. Needle anatomy in cross section: hypodermis biform, of 2-4 layers; endodermis of thin-walled cells; resin canals 3-9, medial or medial and internal, mostly small.

Mature cones sessile or nearly so, 4.5-6.5 cm. long, when closed ovoid and 3.5 cm. wide, when open ovoid, almost as broad as long, flat at base, 5-6 cm. wide, frequently early dehiscent, persistent. Cone scales spreading, lower ones slightly reflexed, mostly 6-10 mm. wide; apophysis keeled though keel weak on basal scales, tawny yellow, slightly shiny or dull; umbo ending in small slender prickle about 1-2 mm. long, mostly persistent, smaller on basal scales. Winged seeds about 19-24 mm. long, including detachable brown wing and 3-angled body 5 mm. long and blackish.

Representative specimens: *Little and Little 17321,* September 23, 1959, Dias Creek, Middle Township, Cape May County, New Jersey; and *E. L. Little, Jr., 21276,* November 8, 1965, Beltsville Experimental Forest, Prince Georges County, Maryland.

Pinus serotina X taeda (Pond Pine X Loblolly Pine)

Pinus serotina X *taeda,* pond pine X loblolly pine, or pond-loblolly hybrid pine. Natural hybrid tree with leaves and cones intermediate between *Pinus serotina* Michx. (Fl. Bor.-Amer. 2: 205. 1803), pond pine, and *P. taeda* L. (Sp. Pl. 1000. 1753), loblolly pine. Medium-sized tree 12 m. (40 ft.) or more in height and 20 cm. (8 in.) or more in trunk diameter. Bark dark gray, rough, furrowed into scaly plates. Trunk usually without short twigs and leaves. Buds cylindric, acute, reddish brown, resinous.

Leaves 3 in fascicle, flexible to slightly stiff, 12-21 cm. long, 1.4-1.6 mm. wide, serrulate, green; whitish stomatal rows 11-13 on dorsal surface and 7-9 on each ventral surface. Needle anatomy in cross section: hypodermis biform, of 2-4 layers; endodermis of thin-walled cells; resin canals 4-5, medial or medial and internal, mostly small.

Mature cones sessile or nearly so, 7-9 cm. long, when closed conic or narrowly ovoid and 3.5-4.5 cm. wide, when open ovoid, broadest below middle, flattened at base, 5.5-6 cm. wide, early or late dehiscent, partly persistent. Cone scales spreading, lower ones slightly reflexed, mostly 9-13 mm. wide; apophysis keeled though keel weak on basal scales, tawny yellow, dull; umbo ending in small, slender, sharp, persistent prickle about 2-3 mm. long, smaller on basal scales. Winged seeds about 24-27 mm. long, including detachable brown wing and rhomboid or ovoid body 6-7 mm. long, blackish.

Representative specimen: *Little and Little 17336,* September 24, 1959, 7 miles west of Milton, Sussex County, Delaware.

Pinus rigida X taeda
(Pitch Pine X Loblolly Pine)

Pinus rigida X *taeda,* pitch pine X loblolly pine, or pitch-loblolly hybrid pine. Natural hybrid tree with leaves and cones intermediate between *Pinus rigida* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 10, 1768), pitch pine, and *P. taeda* L. (Sp. Pl. 1000. 1753), loblolly pine. Medium-sized tree 8 m. (26 ft.) or more in height and 15 cm. (6 in.) or more in trunk diameter. Trunk usually without short twigs and leaves. Buds cylindric, acute, reddish brown, resinous.

Leaves 3 in fascicle, slightly stiff, 10-19 cm. long, 1.1-1.5 mm. wide, serrulate, green; whitish stomatal rows 10-15 on dorsal surface and 5-9 on each ventral surface. Needle anatomy in cross section: hypodermis biform, of 2-4 layers; endodermis of thin-walled cells; resin canals medial, 2-4, 2 large at angles and others small.

Mature cones sessile or nearly so, 5-6 cm. long, when closed conic and 3.2-3.5 cm. wide, when open ovoid, flattened at base, 4.5-6 cm. wide, persistent. Cone scales spreading, lower ones slightly reflexed, mostly 8-13 mm. wide; apophysis with prominent transverse keel, tawny yellow, slightly shiny or dull; umbo ending in small, slender, sharp, persistent prickle about 2 mm. long. Winged seeds 21-22 mm. long, including detachable wing and 3-angled body 4.5-6 mm. long.

Representative specimens: *S. Little 4,* February 7, 1962, natural reproduction around loblolly pine plantation, Lebanon State Forest, Burlington County, New Jersey; *E. L. Little, Jr., 21277,* November 8, 1965, Beltsville Experimental Forest, Prince Georges County, Maryland.

The description of *Pinus rigida* X *taeda* is based upon the natural reproduction around a loblolly pine plantation at Lebanon State Forest, Burlington County, New Jersey, and natural hybrids on the Beltsville Experimental Forest in Maryland. The New Jersey plants were compared with artificial hybrids of the same cross made at the Institute of Forest Genetics, Placerville, California, and growing at the Lebanon State Forest.

DISTRIBUTION OF SPECIES AND HYBRIDS

Species

The natural ranges of the three species are mapped in the respective station papers on silvical characteristics *(15, 25, 26)*. Loblolly pine is found on the Coastal Plain or Piedmont from Delaware to Florida and Texas. The published map *(25)* shows loblolly pine's botanical range as extending into northern Delaware, and Taber *(24)* mentions a natural outpost on the banks of the Delaware-Chesapeake Canal in New Castle County. However, its occurrence north of Dover is rare, and in Delaware it is found principally in lower Kent and Sussex Counties *(24)*.

Long *(17)* and others recorded loblolly pines in southern New Jersey, but we wonder whether these trees were planted or descended from planted trees. This species was not reported from New Jersey until 1897, and then only from a few locations in lower Cape May County *(22)*. Because of the natural reproduction near later plantations in other counties of southern New Jersey, the Cape May trees cited by Stone and Long, as well as the occasional stands found there today, may be descended from early ornamental plantings. On the other hand, District Forester Charles W. Holsworth suggests that loblolly pines found west of dwellings at Dias Creek in Cape May County and near Dividing Creek in Cumberland County, both areas not far from Delaware Bay, may form natural outposts of this species.

Pond pine is found chiefly on wet soils and in swamps of the southeastern Coastal Plain from southern New Jersey to Alabama and Florida. This range is almost entirely within that of loblolly pine, but smaller. At present the known occurrence of pond pine in New Jersey is limited to Cape May County and to southern portions of Cumberland County, although Stone *(22)* mentioned that it was also found near Swedesboro in Gloucester County. In Delaware, Taber *(24)* found pond pine growing both on wet sites and on dry, sandy soils—mostly in Sussex County, but to some extent also in Kent County.

Pitch pine is an upland tree of the mountains from northern Georgia northward through Pennsylvania and scattered to the Canadian border and New England. However, it descends to the Coastal Plain and river valleys, especially from New Jersey northward to Maine. Although commonly considered as a tree of shallow soils on ridges, it grows too on imperfectly to very poorly drained sands, even in the Atlantic white-cedar swamps, in the Northeast. It is the commonest pine of the New Jersey pine barrens. Although two publications *(15, 24)* indicate its occurrence in southern Delaware, the authors of this paper did not find typical specimens of pitch pine in the southern part of the state. Typical trees of pitch pine may well be confined to the northern part of the state, possibly as scattered outposts of the greater concentration of this species in the Maryland barrens west of Elkton.

Apparently pitch and pond pines have almost entirely separate ranges, which meet only in narrow restricted areas in southern New Jersey, especially lower Cape May County, and possibly in central Delaware and the central portion of Maryland's Eastern Shore. When maps of these two species are united, a peculiar distribution pattern results (*12,* p. 769).

Pitch and loblolly pines also have almost entirely separate ranges. However, both occur naturally in the upper portion of Maryland's western shore—chiefly in Prince Georges County.

Present distribution patterns of all three species probably were affected by Pleistocene glaciation, though evidence of past distribution is lacking.

Hybrids

Because they are usually geographically separated, pitch and pond pines have relatively few natural hybrids or intergrades. Intergrades can be found in spots in Cape May County, New Jersey, and near Beltsville in Prince Georges County, Maryland.

In Delaware there seems to be a tendency to grade from typical pond pine in Sussex County toward pitch pine in the vicinity of Dover. Whether the decreased length of needles observed on some of the latter trees is evidence of some pitch pine ancestry is questionable. Therefore, on the whole, the hybrids or intergrades between pitch and pond pines are chiefly of taxonomic interest.

A similar difference in geographic ranges has prevented widespread occurrence of natural hybrids or intergrades between pitch and loblolly pines. However, these hybrids do occur in Prince Georges County, Maryland. Other hybrids should be expected wherever loblolly pines have been successfully planted within the range of pitch pine. For example, reproduction developing around the older plantations of loblolly pine in southern New Jersey contains apparent hybrids between these two species.

In contrast, natural hybrids and intergrades between loblolly pine and pond pine are more widespread. They can be found quite commonly throughout southern Delaware: from Marydel and Dover south to the Maryland line, as well as along the dunes below Rehoboth Beach. In Maryland similar hybrids and intergrades are less common, and typical trees of loblolly pine are much more prevalent. However, the hybrids and intergrades have been observed, especially in the vicinity of the Wicomico State Forest, south in the vicinity of the Nassawango Creek to the northern portion of the Pocomoke State Forest. This general section has had more wildfires than usual for the Eastern Shore, and the fires have doubtless played a major role in favoring pond pine and its hybrid since these trees are more fire-resistant, but slower growing, than the typical loblolly pine. In fact, within that general section the prevalence of pond pine and its hybrids is closely associated with the recent fire history.

In both Delaware and Maryland, pond pine and its hybrids or intergrades are not restricted to wet sites, but are found on a wide variety of soils. In much of southern Delaware, hybrids or intergrades between pond and loblolly pines seem more common than typical trees of the latter.

IMPORTANCE IN FORESTRY PRACTICE

The differences between loblolly pine and pond pine are important in the practice of forestry in Delaware and on Maryland's Eastern Shore, mainly because pond pine is slower growing, has less desirable form and clear length than does loblolly. At 50 years on the usual 80- to 85-foot sites, a typical pond pine is 13 to 15 feet shorter, with a smaller diameter than nearby typical loblolly pines (fig. 3). Some of the intergrades or hybrids approach typical loblolly in growth and form, but many are intermediate. Artificially produced pitch-loblolly hybrids have also grown more slowly on the Eastern Shore than regular nursery stock of loblolly: dominant loblolly pine trees (about 125 per acre) at 17 years after planting were 44 or 45 feet tall, and dominant pitch-loblolly hybrids at 17 years were 33 to 37 feet tall (table 2 and fig. 1). In fact, the growth of these hybrids was similar to that of shortleaf pine, a species with a growth rate comparable to that of pitch pine. Obviously forestry practices should favor regular loblolly pine over pond pine or intergrades,

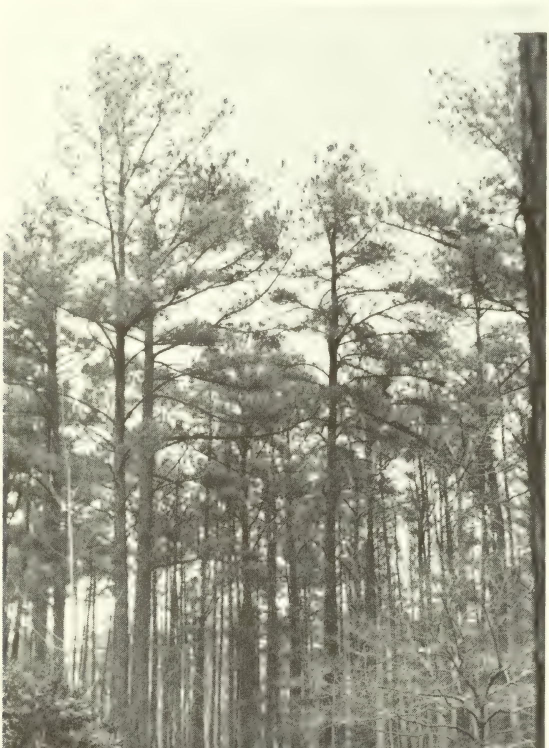

Figure 3. — Comparative heights of loblolly and pond pines. The loblolly pine at the left of the photograph is 87 feet tall; the pond pine in the center is 74 feet tall.

Table 2.—*Size of artificial hybrid pines and ordinary nursery stock 17 years after planting*[1]

Nursery	Stock	Average diameter (b.h.) of all living stems	Largest stems[2]	
			Diameter	Height
		Inches	*Inches*	*Feet*
	WICOMICO STATE FOREST, MARYLAND			
Green Bank, N. J.	Loblolly	9.0	10.4	44
	Pitch (V6) X loblolly (V22)	6.4	8.3	37
	Shortleaf	5.6	7.3	35
Milford, Del.	Loblolly	8.6	10.7	45
	Pitch (V28) X loblolly (V22)	6.1	8.1	36
	Pitch (V27) X loblolly (V22)	6.8	8.1	34
	Pitch (V29) X loblolly (V22)	5.7	6.8	33
	LEBANON STATE FOREST, NEW JERSEY			
Green Bank, N. J.	Loblolly	4.9	5.2	23
	Pitch (V6) X loblolly (V22)	4.2	5.4	22
	Shortleaf	3.7	4.6	23

[1] For a description of this study, see Little and Somes *(16)*. These artificial first-generation hybrids were grown from seeds obtained from the Institute of Forest Genetics, Placerville, California.

[2] At the rate of about 125 per acre.

since favoring loblolly alone would increase the site index by 10 to 15 feet.

In mixed immature stands with a small proportion of pond pine, competition alone will eliminate many stems of the slower growing species. However, any thinnings for pulpwood or other products should discriminate against the pond pines.

In mature stands seed trees should be selected from dominant loblolly pines. Such a procedure would reverse the trend that has been apparent in much of Delaware. There commercial selective cuttings have usually removed the larger pines, principally loblolly, often leaving pond and Virginia pines as the available seed sources.

The importance of differentiating loblolly pine from pond pine and its intergrades cannot be overemphasized in collecting seed for forest nurseries. The prevalence of hybrids and intergrades in Delaware makes the collection of typical loblolly seeds more difficult there than in Maryland. However, few intergrades will be included if collections are limited to large cones with stout prickles from trees that have few cones older than 1 year, and that have non-resinous buds and relatively long, flexible needles.

On the other hand, the ease with which loblolly can be crossed with pitch pine suggests that perhaps the hybrid should be given greater consideration for planting north of loblolly's natural range. Like the mass-produced hybrids in Korea, some of these hybrids might be expected to be both hardier than loblolly and somewhat faster-growing than pitch pine. The only test plantings to date were of crosses made by the Institute of Forest Genetics of the Pacific Southwest Forest and Range Experiment Station, Placerville, California. On a deeply leached, sandy (Lakewood) soil in New Jersey, these hybrids have had the best survival, 50 percent after 17 years (compared to 41 percent for regular shortleaf stock and 11 percent for regular loblolly stock).

Height and diameter growth of the hybrids has been roughly comparable to both loblolly and shortleaf stocks (table 2), probably because the site is so poor that shortleaf's growth approaches loblolly's. On better soils in southern New Jersey, loblolly pines grow faster: in 29-year-old plantations in one field, dominant and codominant loblolly pines were 57 feet tall; shortleaf pines, 42 feet tall; pitch pines, 41 feet tall. And in natural reproduction around the older plantations of loblolly pine, some of the natural hybrids with pitch pine are growing nearly as fast, and with nearly as good form, as the loblolly pine seedlings. They seem to offer promise that certain of the hybrids would be at least superior to pitch pine seedlings.

These observations suggest that further tests of loblolly-pitch pine hybrids are desirable. Possibly the relatively poor results in the existing trial are due to geographic sources of the parents. Since both species have wide ranges and apparently local geographical races, future tests of loblolly-pitch pine hybrids in the Northeast will be based on Maryland or Delaware sources of loblolly pine and the best local strains of pitch pine.

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Some Observations on CAMPGROUND TRAMPLING & Ground Cover Response

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1967

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

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Some Observations on CAMPGROUND TRAMPLING & Ground Cover Response

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Trampling, a Threat to Natural Growth

TRAMPLING of recreation sites frequently has been reported as a serious threat to the natural attractiveness of developed recreation areas (Clawson 1959, DeVoto 1953, James and Ripley 1963). Previous studies of the impact of trampling upon soils and plants have been restricted almost entirely to after-the-fact analyses of forested parks and playgrounds that have been used and over-used for decades (LaPage 1962, Lutz 1945, Magill and Nord 1963, Meinecke 1929). Much valuable information about species tolerance levels and rates of decline has never been collected because after-the-fact studies make it impossible to reconstruct the appearance of soils and plants at different stages of park use. However, Wagar (1964) made a major advance in gaining information about species tolerance when he studied simulated recreation conditions in which different intensities of recreation use were applied to a narrow range of soils and vegetation to measure their reaction to trampling.

A more useful method of gaining the needed information would be to measure vegetative change concurrently with actual recreation use. Therefore, in 1963, the Northeastern Forest Experiment Station began a continuing study to record changes that occur in the composition and density of ground cover on a series of permanent plots located throughout 17 units of a 40-unit campground in the new Buckaloons camping area in the Allegheny National Forest.

The Buckaloons campground is located on a flood plain of the Allegheny River in northwestern Pennsylvania. The soil here is Chagrin silt loam, a deep, well-drained, and productive soil originating from sediments of sand, silt, and gravel washed down from the glaciated upland. The vegetation present at the time the campground was established was that of a typical abandoned field containing an abundance of grass, moss, violets, goldenrod, asters, and associated species. Parts of the field were overgrown with a fairly dense stand of hawthorne, which provided some screening between camping units, but no shade.

The past 3 years of observation on these plots have produced several interesting and useful clues about the nature of trampling in an old-field type campground.

First-Year Findings

Just before the campground was opened to the public in June 1963, the low-growing vegetation on all plots was photographed, and plant density and species composition were determined by using a transparent 4-inch-square grid containing 100 evenly spaced dots (fig. 1). Plant density was recorded as the percent of living or dead ground cover (attached vegetation) present on six randomly selected 4-inch-square sampling units within each plot. Before camping use, most of the plots contained a dense 100-percent cover, averaging 11 species per campsite.

Re-examination of the plots in September 1963, after a season of use, revealed a reduction in the abundance of vegetative cover as well as fewer plant species present. The average loss of plant cover for all campsites was found to be 45 percent. Campsites that had received 150 camper-days of use throughout the summer averaged less than a 10-percent loss in vegetative cover. However, loss of vegetative cover increased to 60-percent for 300 camper-days of use (fig. 2).

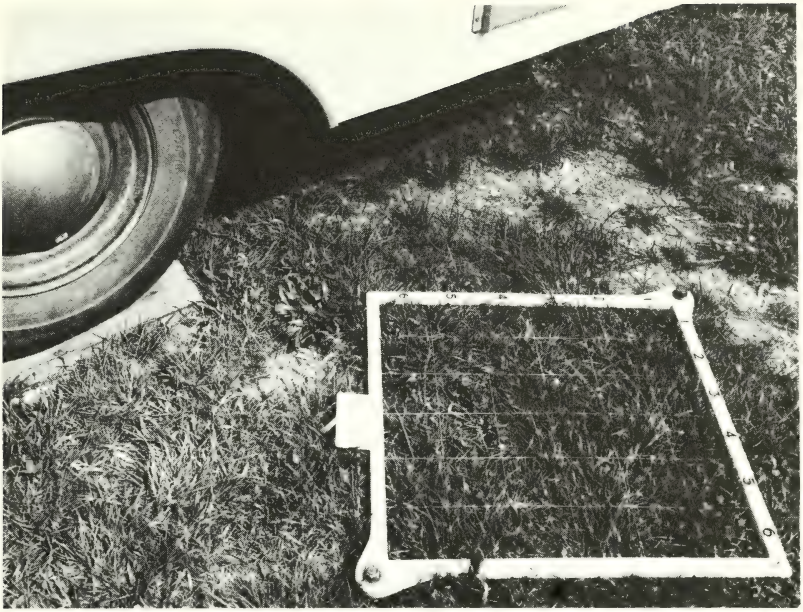


Figure 1.—Four permanent sample plots like this one were located at the center of each campsite. No restrictions were placed on trailer parking or other activities so that all sites would experience normal camping pressures.

The logarithm of camper-days use and reduction of ground cover, presented in figure 2, provides the best description of the relationship and explains 78-percent of the variation in ground cover present at the end of the first year. This curvilinearity indicates, for this site at least, that restricting the average amount of use to 200 campers or fewer per season might be a feasible way of minimizing native cover loss.

Such severe restrictions are hardly an economic use of developed resources and may only be prolonging the inevitable anyway. Subsequent observations made during the second and third years suggest that the original ground cover composition is probably destined for replacement by more resistant species.

Reductions in the number of species making up the ground cover were not significant during the first year. Throughout the 17 sites, the average number of species declined from 11 to 9.

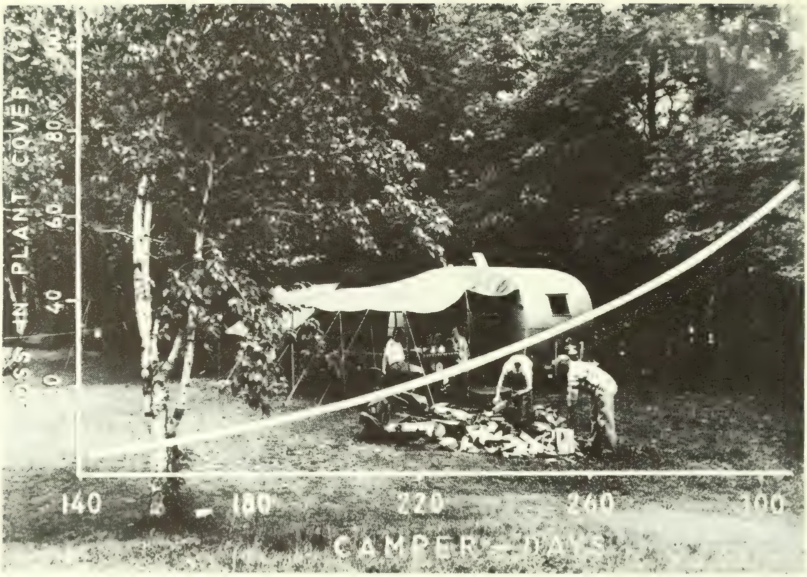


Figure 2.—Loss of ground cover (as a percent of original cover) on an old field campground during the first year of campground use. This relationship is expressed by the formula:
Log % cover loss = —6.991 + 3.541 log camper-days.

Three campsites actually showed a slight increase in the number of species present.

The plants most seriously reduced at the close of the season were the larger species such as goldenrod and asters. Those specimens that remained were usually restricted to a single basal rosette. Also, large carpets of moss, present in the spring, were badly damaged by fall.

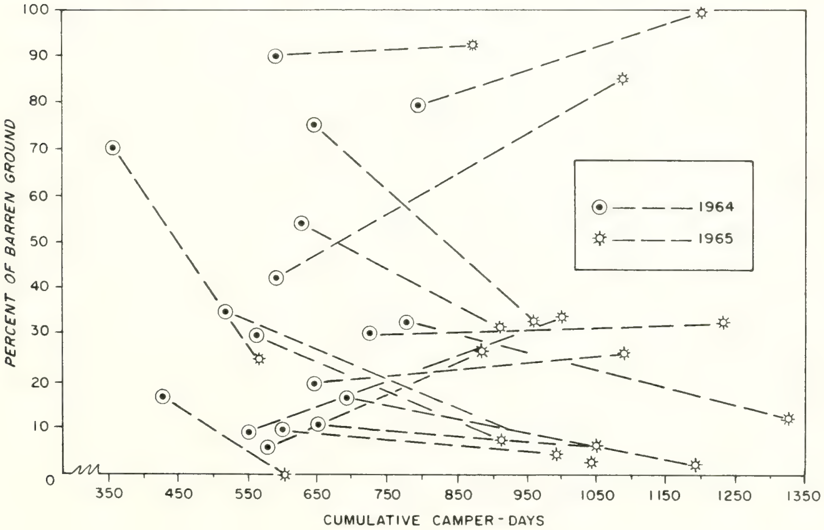
A fairly distinct size rule seemed to be operating in favor of the smaller annual plants during this first year. Small-leaf plants such as yarrow, sheep sorrell, and oxalis fared better than violets and cinquefoil, but not as well as the narrow-leaved grasses. Even among the grasses, the size rule seemed to operate, with orchard grass showing less tolerance to trampling than bluegrass or bent grass. This superior tolerance of grasses over dicotyledonous herbs agrees with the findings of Wagar (1964) on plant response to simulated recreation use in Michigan, and with that of Bates (1935) on the vegetation of compacted footpaths in England.

Second-Year Findings

From the fall of 1963 to the spring of 1964 the study sites received little use and recovered nearly half of the vegetation lost during the previous camping season, leaving them approximately 26-percent barren at the start of the second summer. By fall, cover losses had again increased, but only to 37-percent of the area. This 9-percent gain in cover over the previous fall occurred during an exceptionally dry summer when camping use had increased from an average of 237 days in 1963 to 351 days per site in 1964.

The variation present in campsite cover conditions by the fall of 1964 reflected a direct relationship with total campsite use, but showed no relationship with second-year use-intensity alone. Apparently the strong effect of the first year of use on the area continued to be evident after 2 years of cumulative use. However, as the barren ground became revegetated with a more re-

Figure 3.—The distribution of barren ground in 1964 and 1965 according to the intensity of cumulative use. The variability in plot condition in 1964 alone reflects a direct relationship with use intensity. This direct relationship had disappeared by the fall of 1965. The change in plot condition from 1964 to 1965 (dashed lines) shows no consistent relationship with cumulative use.



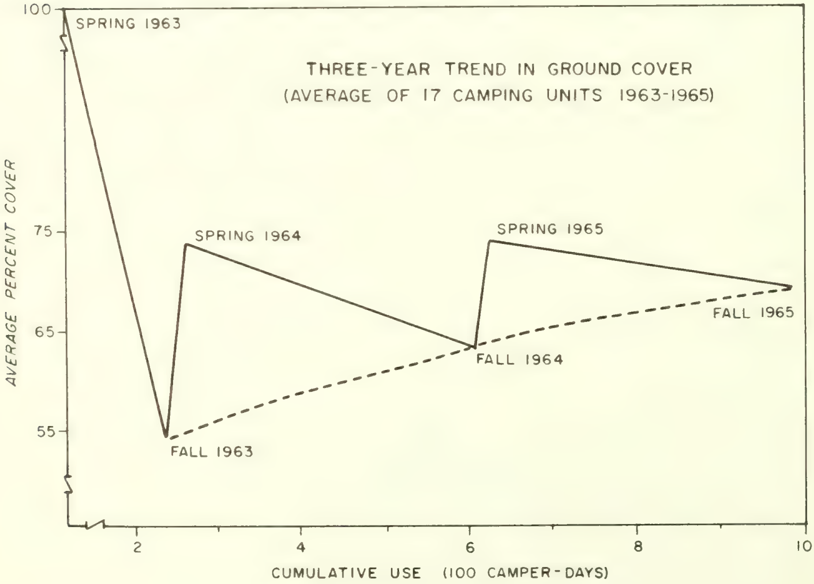
sistant cover, the relationship between barren ground and cumulative man-days of use weakened and disappeared entirely by the end of 1965 (fig. 3).

Most of the original species present in early 1963 had become less abundant by the fall of 1964. Although the field originally supported a dense growth of goldenrod, only an occasional stunted specimen could be found. Some of the original species, particularly bluegrass, had greatly increased in abundance. And a new species that thrives on compacted sites—path rush—had become increasingly common. The average number of species per campsite was reduced to six by the end of the second season.

Third-Year Findings

The relationship between use intensity and campsite condition became even more erratic in 1965. Under increasing pressures of use, some sites continued to lose ground cover, others gained, and still others barely changed (fig. 3).

Figure 4. — Annual and seasonal change in average ground cover on 17 campsites subjected to normal camping pressures.



Average campsite use increased to 368 camper-days, and average barren area stood at 31 percent in the fall after a recovery to 26 percent in the spring (fig. 4). The change in campsite condition from the end of the second to the end of the third camping season reflected a general pattern of increasing cover occurring simultaneously with increasing use (fig. 3). This general improvement in campsite condition was clearly the result of more resistant species taking over the barren ground previously occupied by the original plant community.

Although occasional specimens of the broad-leaved community have survived, and a few pioneer species have appeared, the total number of species has declined steadily during these 3 years of campground use. Both the total species represented and the average numbers of species per campsite have been reduced by more than 50 percent.

		Total species (No.)	*Average per site (No.)*
1963:			
	Spring	37	11
	Fall	29	9
1964:			
	Spring	31	11
	Fall	23	6
1965:			
	Spring	19	6
	Fall	17	5

By an annual ranking of species according to their frequency of occurrence (maximum frequency would be 17) it is possible to arrive at some tentative conclusions concerning the relative tolerance of various species to trampling (table 1).

Among the relatively tolerant species, bluegrass moved from a rank of 3 in 1963 to 17 in 1965; path rush appeared on 2 sites in the fall of 1963 and spread to 9 sites 2 years later, and bent grass was one of the 3 most abundant species every year. Among broad-leaved plants, clover was the only species to demonstrate any real tolerance of trampling.

Rapidly declining species that were originally abundant were cinquefoil, goldenrod, wild strawberry, and fescue, which were all eliminated; and yarrow, oxalis, sheep sorrel, and moss, which were seriously reduced over the 3-year period.

Table 1.—*Plant species present and their frequencies of occurrence during spring and fall examinations for 3 years of camping-use*

Species[1]	Frequency					
	1963		1964		1965	
	Spring	Fall	Spring	Fall	Spring	Fall
Cinquefoil *(Potentilla)*	14	5	10	2	1	0
Yarrow *(Achillea)*	14	10	10	5	5	3
Bent grass *(Agrostis)*	13	15	16	13	16	13
Fecue *(Festuca)*	13	10	4	3	1	0
Goldenrod *(Solidago)*	12	4	9	0	0	0
Hair-cup moss *(Polytrichum)*	11	8	13	9	8	3
Wood sorrel *(Oxalis)*	10	7	9	1	0	1
Sheep sorrel *(Rumex)*	9	11	12	5	5	4
Speedwell *(Veronica)*	9	4	10	3	1	0
Violet *(Viola)*	9	9	11	5	7	4
Wild strawberry *(Fragaria)*	8	7	7	1	0	0
Timothy *(Phleum)*	6	0	2	3	3	3
White heath aster *(Aster)*	5	3	0	0	0	0
Buttercup *(Ranunculus)*	4	3	3	2	4	1
Loosestrife *(Lythrum)*	4	2	3	0	0	0
Plantain *(Plantago)*	3	5	6	5	6	4
White campion *(Lychnis)*	3	6	4	4	6	3
Clover *(Trifolium)*	3	3	10	7	8	9
Orchard grass *(Dactylis)*	3	1	3	2	4	2
Bluegrass *(Poa)*	3	11	12	14	15	17
Sedge *(Carex)*	2	2	2	1	0	0
Nettel *(Urtica)*	2	0	1	0	0	0
Foxtail *(Setaria)*	2	2	4	0	0	0
Heal-all *(Prunella)*	2	2	0	0	0	0
Milkwort *(Polygala)*	2	0	0	0	0	0
Grapefern *(Botrychium)*	1	0	0	1	0	0
Dandelion *(Taraxacum)*	1	1	0	0	0	0
Hawthorne *(Crataegus)*	1	1	2	0	0	0
Field mint *(Mentha)*	1	0	0	0	1	0
Hawkweed *(Hieracium)*	1	1	1	1	0	0
Bindweed *(Convolvulus)*	1	1	0	0	0	0
Wild rose *(Rosa)*	1	0	1	0	0	0
Wild onion *(Allium)*	1	0	0	0	0	0
Wild carrot *(Daucus)*	1	1	3	0	0	0
Field madder *(Galium)*	1	0	0	0	0	0
Wild parsnip *(Pastinaca)*	1	1	1	0	0	0
Elder *(Sambucus)*	1	0	0	0	0	0
Path Rush *(Juncus)*	0	2	3	6	8	9
Chickweed *(Cerastium)*	0	0	4	2	3	2
Bluet *(Houstonia)*	0	0	1	0	0	0
Fall panicum *(Panicum)*	0	0	2	5	2	4
Mustard *(Brassica)*	0	0	0	0	0	1

[1] All species identifications are tentative because specimens were often badly mutilated by rampling and could not be removed from the plots for detailed examination without damaging he study's basic objective of determining plant survival under actual trampling conditions.

Discussion

Maintenance of a vigorous ground cover is probably not a primary concern of most campground managers. However, trampling, as it affects long-term recreation-management goals has an undeniable influence on site preservation. And this campground with its abundant and varied ground cover provides an ideal opportunity to study campground ecology. Although only 3 years of observation have been compiled, several interesting and potentially useful aspects of trampling have been uncovered.

Ground cover losses were generally higher on camping units with stationary picnic tables. Movable tables apparently help to spread the wear and prevent the early formation of paths between fireplace, table, and parking space.

Revegetation with bent grass, bluegrass, and path rush was often best in areas where large patches of moss had died, but where enough stems had remained to trap the wind-blown seed and hold it against bare soil. Campground management could probably duplicate this effect by spreading a thin layer of straw on bare spots immediately after the Labor Day weekend. A logical extension of this revegetation process would be the direct seeding of these grasses, accompanied by restrictions on use during the late fall and early spring months when sites are damp and most easily compacted.

Some of the most lightly used campsites were also the ones that experienced the greatest loss of ground cover. In each of these cases some unusual circumstance of campsites use was evident as the probable cause of accelerated wear. Loose, abrasive, gravel that had strayed from the campground roads, from the built-up tent pads, or from crumbling fireplaces (fig. 5) was frequently found on campsites that had experienced an unusually heavy cover loss. Other sites used lightly, but effectively screened from sun and air for extended periods of time by plastic ground cloths and canvas tent floors, also experienced excessive loss of vegetation.

These observations indicate that trampling, expressed simply as man-days of use, is not an adequate measure of the impact of camping on vegetation. Some measure of the quality or character

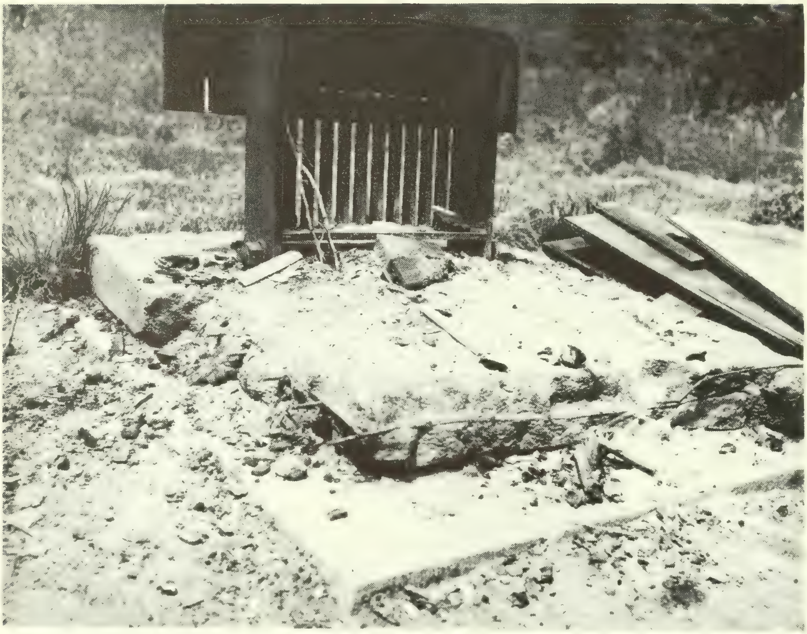


Figure 5.—Rubble from this disintegrating fireplace is scattered over a wide area, and its abrasive action underfoot will accelerate the destruction of existing ground cover.

of recreation use is needed that will explain the destruction of ground cover more realistically than simple use intensity does.

The following conclusions have resulted from observations on this study to date:

- An initial and inevitable heavy loss of ground cover follows the onset of camping-use, and the extent of the loss is strongly related to the intensity of first-year use, expressed as camper-days.
- The plant species composition of the original cover undergoes a gradual rearrangement, in which the more compaction —and drought-resistant species become increasingly abundant.
- During the second, third, and following years the recreation-tolerant species advance while the original less-resistant species continue to retreat, with the result that the cover does

not respond to continued trampling in the same direct way that it did during the first year.

At present a more resistant ground cover is spreading over these campsites. From observations at other recreation areas it seems inevitable that this second growth will also decline under sustained trampling. Continued observation will make it possible to document the rate and nature of this decline.

But, similar studies will be needed of other sites and cover types. Ideally, these studies should include three distinct phases. During the initial phase those plant species of the original community that have the highest natural tolerance to trampling are identified. Second, by observing the subsequent decline of these species, it will be possible to determine their limits of endurance. This information should be of value in formulating realistic recreation-site management objectives. And, in the third and final phase, various methods of site rehabilitation can be tested to provide remedial measures for those recreation areas where plant tolerance limits have been exceeded.

These findings, along with those from similar studies on different sites, will help to provide guidelines for the design and intensive management of campgrounds to improve their ability to provide a sustained supply of high quality outdoor recreation experiences.

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A cost analysis of CHIP MANUFACTURE at hardwood sawmills

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A cost analysis of CHIP MANUFACTURE at hardwood sawmills

■

AN OPPORTUNITY TO INCREASE INCOME

BECAUSE of the growing need for wood fiber in the pulp and paper industry, there is an opportunity for sawmill operators to increase their income by converting hardwood sawmill residues (slabs, edgings, and trim) to pulp chips. By selling wood chips and reducing residue-disposal costs, sawmills could improve their utilization of sawlogs.

But to justify the installation of debarking and chipping machines, and to know what such machines could contribute to his business, the sawmill owner must have a thorough understanding of the costs involved in chip production.

To help him in this we have made case studies of seven sawmills in southeastern Ohio, eastern Kentucky, and Tennessee, and have analyzed all the factors of cost involved in chip production.

THE STUDY APPROACH

When a sawmill, which is accustomed to producing lumber as its sole product, undertakes to produce wood chips from its residues, some of the cost factors change. The merging of chip production with lumber manufacturing modifies or replaces certain of the operations that are necessary in producing hardwood lumber.

For example, if a sawmill owner invests in debarking and chipping machines for producing wood chips, the cost of these machines can logically be charged to chip production. But at the same time, these same machines are also used in operations that contribute to lumber production. And these machines have side effects on lumber production. For example, debarking logs before sawing them changes saw-maintenance requirements and affects lumber production rates. The cost changes in lumber production are chargeable to debarking, which is a step in chip production.

Therefore the cost for the sawmill to produce pulp chips may be viewed as the change in its total net cost resulting from sawlog-debarking and chip-production activities. It costs a given amount per thousand board feet to produce lumber if logs are debarked and wood residues are chipped. Without debarking and chipping facilities in the mill it would cost a different amount to produce the same lumber. This cost difference expresses the change caused by debarking and chipping facilities, regardless of whether they were included in the original sawmill construction or were installed later.

All sawmills included in this study were in operation before embarking upon chip production. These mills (three band mills and four circular mills) were selected to determine cost changes in lumber-production activities caused by addition of log-debarking and chip-producing facilities.

To compute pulp-chip production costs as the change in total net cost to the sawmill firm, the following items were considered chargeable to chip production:

- Fixed costs (debarking and chipping), including (1) equipment depreciation charges, (2) interest charges, (3) insurance, and (4) taxes.

Table 1.—Average hardwood chip-production costs for seven sawmills

Item	Cost		
Chip-production rates:			
1. Daily average 19 tons			
2. Annual average 4,525 tons			
Chip-production costs:			
3. Fixed cost:	*Annual cost*		*Cost/ton of chips*
Depreciation	$4,435.50	=	$0.98
Property tax	339.00	=	.08
Insurance	411.00	=	.09
Interest on average investment	1,514.75	=	.33
All fixed costs	—		$1.48
4. Variable costs:	*Daily cost*		
Labor:			
Debarker	15.20	=	$0.80
Chipper	13.87	=	.73
Power:			
Debarker	—		.12
Chipper	—		.33
Maintenance & repair:			
Debarker	—		.16
Chipper	—		.42
All variable costs	—		$2.56
5. Total cost	—		$4.04
Change in lumber-production cost:			
6. Variable cost saving:	*Per MBF*		*Per ton of chips*
Saw maintenance	$0.42	=	$0.34
Log washing	.67	=	.55
Wood residue disposal	.29	=	.24
Total variable cost saving	$1.38		$1.13
Total net cost to firm per chip-ton (at sawmill):			
Chip-production costs	—		$4.04
Lumber production savings	—		1.13
Net cost per ton of chips	—		$2.91

- Variable costs (debarking and chipping), including (1) labor, payroll-based taxes, and insurance; (2) power (electricity); (3) equipment maintenance, parts, and labor; and (4) raw material.
- Cost changes in activities altered by debarking and chipping: (1) saw maintenance, (2) sawlog cleaning, (3) wood-residue disposal, and (4) supervisory and office overhead.
- Chip transportation costs.

Costs for the above items were compiled at each mill. From this information an all-mill weighted average cost per ton of chips (green) was computed for each expenditure item (table 1). The weighted averages are used in the following discussion of individual expenses.

ANALYSIS OF CHIP-PRODUCTION COSTS

Depreciation Charges

Depreciation of buildings and debarking and chipping equipment — including associated facilities such as bark drags and slab and chip conveyors where applicable — was treated as an annual expense, permitting an even spread of these charges over chip production for the entire useful life of the equipment. The expected useful or productive life of these facilities varied from 6 to 15 years depending mainly upon the amount of use in terms of annual chip production. The weighted average output of chips for all mills amounted to 4,525 tons annually. The average indicated useful life of equipment was 9 years. The following equation illustrates the method of calculating depreciation:

$$\text{Annual depreciation} = \frac{I - R}{N} = \$4{,}435.50$$

Where:

I = Purchase cost of $32,402 plus installation cost of $10,586 = $42,988.

R = Estimated salvage value after N years = $3,068.

N = Expected useful life = 9 years.

Interest Charges

Interest charges represent income foregone by investing capital in debarking and chipping facilities rather than in securities or some other investment. Since annual depreciation allowances are presumably funds available to the firm, they should be earning interest. Therefore calculated interest charges are based on the average investment — the average profit-bearing capital at work in the operation. Using the same values from the calculation of depreciation, average profit-bearing capital would be:

$$\text{APBC} = \frac{(\text{I}-\text{R})\ (\text{N}+1)}{2\text{N}} + \text{R} = \$25{,}245.78$$

And using an interest rate of 6 percent:

$$\text{Annual interest charges} = 6\%\ (\$25{,}245.78) = \$1{,}514.75$$

Insurance and Taxes

The average amount spent for insurance coverage on debarking and chipping facilities was $411 per year. Although this amounted to 1.6 percent of the average investment, the insurance rates ranged from 0 to 4.9 percent at individual mills. Taxes varied from 0.7 percent to 2.3 percent of the average investment, depending upon mill location, and averaged 1.3 percent ($339).

Labor

Labor costs for equipment operation ranged from $1.25 to $1.60 per hour for base wages. Additional associated employment costs for social security, unemployment insurance, workmen's compensation, and other fringe benefits ranged from 14 to 26 percent of base wages, averaging 19.7 percent. The average base wage for debarker and chipper labor was $1.42 and $1.39 per hour, respectively.

Measurements made at each mill determined the actual amount of labor used daily in chip production. Ranging from 8 to 10 man-hours per day, debarker operation averaged 8.5 man-hours of labor, while chipping facilities required 8.2 man-hours for total daily labor costs of $15.20 and $13.87 respectively. Where mill employees worked more than 40 hours per week the average hourly labor costs were adjusted to include overtime wages.

Power

The volume of sawlogs processed and the resulting lumber and chip output were measured at each mill. Machine operating time and metered electric consumption were recorded. Metered electric consumption was apportioned to each machine on the basis of its installed horsepower and operating time. The all-mill average power consumption per chip ton was 4.86 kwh. for debarking and 13.68 kwh. for chipping. Electric power rates varied from 1.25 cents to 3.65 cents per kwh., averaging 2.44 cents. Accordingly, the average electric power costs for debarking and chipping were 12 cents and 33 cents per chip ton.

Maintenance and Repair

Aside from routine preventive maintenance such as lubricating, sharpening, and adjusting equipment, unexpected and sometimes costly breakdowns can occur. So total maintenance and repair costs are subject to wide variation. To include unusual as well as routine maintenance and repair, parts and labor costs were compiled for the longest production period for which records were available, at each mill. The weighted average cost for maintenance and repair amounted to $.58 per ton, distributed as follows:

	Dollars per ton		
	Parts	*Labor*	*Total*
Debarking facilities	0.11	0.05	0.16
Chipping facilities	.25	.17	.42
Total	0.36	0.22	0.58

Raw Material

Cost for raw material has not been included as a chip-production cost. Raw-material cost is logically charged against the cost of producing lumber. However, in the concept of total net cost change, it is irrelevant whether raw-material cost is charged against chips or lumber; if it were charged to chip production a corresponding saving in lumber production would occur.

CHANGE IN LUMBER PRODUCTION COSTS

Saw Maintenance

Sawing debarked sawlogs reduced the number of saw changes per day and increased daily lumber output at all the mills studied. Some mills reported a reduction in filing time per saw, and circular mills found a marked increase in saw-bit life. Since the basis for these changes was different at band and circular sawmills, comparing changes between the two types of mill is not valid. For each type of mill, however, average changes indicate what may be expected from sawing debarked sawlogs.

Mill type	*Number of saw changes per shift (percent)*	*Daily lumber output (percent)*	*Filing time per saw (percent)*	*Volume sawed between saw-bit replacement (percent)*
Band saw	−25	+6	−14	—
Circular saw	−54	+18	−28	+46

The above comparison suggests substantial differences in saw maintenance between band sawmills and circular sawmills. However, computed cost changes for saw maintenance[1] are not a function of mill type but depend upon the maintenance-cost structure of each mill itself. Consequently we cannot say that cost changes are greater for one type of mill than for the other. But we can say that the all-mill-average saw-maintenance cost was reduced $0.42 per thousand board feet as a result of sawing debarked logs.

Sawlog Cleaning

At six of the seven study mills, sawlog debarking displaced labor that formerly was needed to wash or otherwise clean sawlogs. In effect, these labor costs are no longer chargeable to lumber

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[1] Change in saw-maintenance cost per thousand board feet is the cost for rough sawlogs minus the cost for debarked sawlogs, each computed as:

$$\text{Saw maintenance cost/M b.f.} = \frac{\text{Number saw changes per day} \times \text{Filing time per saw (hrs.)} \times \text{Filing cost per hour}}{\text{Daily lumber output (M b.f.)}} + \frac{\text{Saw-bit cost per set}}{\text{M b.f. sawed between bit replacements}}$$

production, although the laborers may have been retained to operate debarking equipment. In this case the labor cost becomes chargeable to chip production and therefore must be credited as a saving in lumber-production costs.

For example, those mills that now debark logs formerly had an average daily lumber production of 15,750 board feet, requiring 7.91 man-hours or a cost of $12.66 per day to wash sawlogs. Since their log cleaning is now done by debarking and is chargeable to chip production, an average of $.80 per thousand board feet of lumber produced is saved.

Wood-Residue Disposal

Similar labor displacement occurred in wood-residue-disposal activities at three study mills. Before the mills installed chipping facilities their average daily production of 14.1 thousand board feet required 6.83 man-hours or $10.79 per day to keep wood residues moving out of the mill. Now, by chipping their residues, these mills realize an average saving of $0.76 per thousand board feet.

All-Mill-Average Cost Saving

Before determining the average cost saving for all the mills, it was necessary first to measure cost savings on a per-thousand-board-foot basis because changes in saw maintenance, log cleaning. and wood-residue-disposal activities, and the subsequent assignment of some costs to chip production, affect the cost of producing lumber. On this basis, the average cost saving for all the mills was $1.38 per thousand board feet — $0.42 on saw maintenance, $0.67 on log cleaning, and $0.29 on wood-residue disposal (item 6, table 1).

However, to relate the effect of these variable cost savings to chip-production costs, it is necessary to convert these savings to a per-ton basis. Yields of chips varied from mill to mill — ranging between 1.0 and 1.5 tons per thousand board feet of lumber sawed. The average chip yield was 1.22 tons per thousand board feet. Therefore the $1.38 lumber production cost-saving converts to a $1.13-per-ton credit against chip-production costs in figuring this firm's total net cost change.

Supervision and Office Overhead

No measureable change was evident in supervisory or office overhead at any of the mills studied. Consequently their effect upon chip-production cost is considered negligible.

TRANSPORTATION

In the western-Appalachian Region sawmill chips are usually sold f.o.b. sawmill. The chip buyer pays rail freight charges, or a per-ton mileage allowance if chips are delivered by truck. The actual delivery cost varies widely according to the distance and the type of transportation. Maximum one-way truck-haul distances generally range between 50 and 70 miles, but rail service extends market access for sawmill pulp chips to approximately 300 miles.

Additional handling costs result when chips cannot be put directly into truck-trailer or railroad chip cars for the main haul to market. Chip producers located beyond practical truck-hauling distance, and not situated on rail sidings, encounter further costs for transferring chips from the sawmill to the railroad. Where intermediate transfer is necessary, chips are transported in large-capacity dump trucks or palletized portable bins that are moved either by fork lift or dump truck. Typical short-haul costs ranged from 18 to 40 cents per ton-mile. The actual cost varies according to the distance and the method used.

EVALUATING THE OPPORTUNITIES

Although costs per ton for the individual inputs differ from mill to mill, overall chip-production costs are related to the combination of average daily and annual chip output of each installation (table 2).

Effective evaluation of a chipping operation requires identifying all the costs and determining the change in total net costs to the sawmill as a result of producing chips. On the basis of only total cost per ton, for example, pulp-chip production at two study mills would have been unprofitable at a chip price of $6 per ton (at the sawmill). But the corresponding change in total net cost per ton,

Table 2. — Hardwood chip-production costs at study mills

Item	Mill						
	A	B	C	D	E	F	G
Chip-production rates:							
Annual average—tons	1,725	2,250	2,400	4,750	5,725	6,800	8,000
Daily average—tons	14	10	10	20	23	31	32
Chip-production costs:	*Cost per ton (dollars)*						
Fixed costs:							
Depreciation	2.62	1.38	1.06	1.27	0.71	0.80	0.83
Property tax	.17	.15	.14	.06	.05	.02	.08
Insurance	—	.09	.17	.08	.06	.14	.07
Interest on average investment	1.04	.66	.51	.24	.28	.17	.22
All fixed costs	3.83	2.28	1.88	1.65	1.10	1.13	1.20
Variable costs:							
Labor:							
Debarker	0.86	1.50	1.42	0.82	0.70	0.56	0.46
Chipper	.86	.28	1.50	.71	.66	.52	.55
Power:							
Debarker	.05	.15	.40	.18	.01	.03	.07
Chipper	.19	.13	.50	.58	.27	.12	.26
Maintenance:							
Debarker	.17	.14	.18	.23	.15	.18	.06
Chipper	.27	.11	.61	.36	.49	.62	.19
All variable costs	2.40	2.31	4.61	2.88	2.28	2.03	1.59
Total cost	6.23	4.59	6.49	4.53	3.38	3.16	2.79
Change in lumber-production cost:							
Variable cost saving:							
Saw maintenance	0.34	0.31	0.46	0.42	0.31	0.39	0.20
Log cleaning	.94	—	1.70	.75	.41	.56	.41
Wood-residue disposal	.94	—	—	.75	.36	—	—
Total cost saving	2.22	0.31	2.16	1.92	1.08	0.95	0.61
Total net cost per ton at sawmill:							
Chip-production costs	6.23	4.59	6.49	4.53	3.38	3.16	2.79
Lumber production savings	2.22	.31	2.16	1.92	1.08	.95	.61
Net cost per ton of chips	4.01	4.28	4.33	2.61	2.30	2.21	2.18

because of savings in lumber production, indicates that each firm would have a net return from chipping operations even if the assumed price for chips were only $5 per ton.

Disregarding sawing-cost savings also overestimates the volume of lumber output needed to support a sawmill chip-producing facility. Many sawmill chipping operations have been established without benefit of knowledge about how cost changes in sawmill activities are altered by debarking and chipping. Accordingly today's average-size installations do not provide a very good indication of the volume of lumber output required to justify sawmill log debarking and chip production. Whether or not a sawmill has sufficient residue to justify debarking and chipping is best decided by estimating the potential net-cost-change facing the firm if it engages in chip production.

Increasing Output with Purchased Slabs

An awareness of unused chipping capacity has led some firms to supplement their own mill residues by purchasing debarked slabs from other sawmills.

When purchased slabs are processed within the existing capacity of a mill's chipping system (fixed and variable inputs as well as physical capacity), the firm has added expenses for slab purchases and extra chipper maintenance. But the additional chip output makes more efficient use of machines, men, and money, thereby decreasing chip-production costs per ton. For example, at two sawmill firms that supplement their own chip output by purchasing slabs, an average increase of 750 tons per year decreased the production cost per ton by 10 percent (table 3).

Aside from improving the profitability of operations at some firms, purchased slabs also play a key role for small sawmills that otherwise could not support a chipping operation. By planning to supplement their mill's insufficient chippable residue with purchased slabs, these firms may find it possible to justify their entry into the chip-producing business.

Chip Quality and Quantity

Specifications for pulp chips, species, bark content, foreign matter, and type of transportation equipment acceptable to the buyer

Table 3. — The effect on chip-production costs of raising the annual production by purchasing debarked slabs[1]

(Number of operating days = 215)

Item	Chip-production rate								
	1,650 tons/year direct from logs sawed at mill			Additional 750 tons/year from purchased slabs			Combined production 2,400 tons/year		
	Cost per year		Cost per ton	Cost per ton		Added cost per year	Cost per year		cost per ton
Chip-production costs:									
Fixed costs:									
Depreciation	$2,900.00	=	$1.76	—		—	$2,900.00	=	$1.21
Property tax	341.00	=	.21	—		—	341.00	=	.14
Insurance	300.00	=	.18	—		—	300.00	=	.13
Interest	1,366.00	=	.83	—		—	1,366.00	=	.57
All fixed costs	—		2.98	—		—	—		2.05
Variable costs:	*Cost per day*								
Labor:									
Debarker	14.00	=	1.82	—		—	3,003.00	=	1.25
Chipper	13.76	=	1.79	—		—	2,953.50	=	1.23
Power:									
Debarker	—		.29	—		—	478.50	=	.20
Chipper	—		.59	—		—	973.50	=	.41
Maintenance:									
Debarker	—		.16	—		—	264.00	=	.11
Chipper	—		.36	.36	=	270.00	864.00	=	.36
Slab purchase	—		—	3.25	=	2,437.50	2,437.50	=	1.02
All variable costs	—		5.01	—		—	—		4.58
Total cost	—		7.99	—		—	—		6.63

	Per MBF							
Change in lumber-production costs:								
Variable cost saving:								
Saw maintenance	0.46	=	.42	—	—	693.00	=	.29
Log cleaning	2.33	=	2.12	—	—	3,498.00	=	1.46
Total saving	—		2.54	—	—	—		1.75
Total net cost (at sawmill):								
Chip-production costs	—		7.99	—	—	—		6.63
Lumber production savings[1]	—		2.54	—	—	—		1.75
Net cost per ton of chips	—		5.45	—	—	—		4.88

[1] Values are actual weighted averages from two mills that purchase slabs.

are necessarily rigid. Chip buyers indirectly maintain quality-control standards by rejecting shipments or deducting penalties from payments to sawmills that produce substandard chips. But with proper maintenance, adjustment, and operation, the debarking and chipping facilities at hardwood sawmills can produce good quality chips.

Besides quality, chip buyers are also interested in quantity — particularly the assurance of a reliable flow of chips to their plant. This means that sawmills producing chips must be essentially year-round operations.

The quantity or rate of chip output must also be coordinated with the type of transportation available to a sawmill firm. This is usually no problem for mills situated within trucking distance of markets. However, where railroad transportation is necessary the situation is more complex. Railroad chip-cars vary in capacity from 35 to 70 tons. And mills loading chip-cars must have sufficient production or storage facilities, or both, to avoid demurrage charges for detaining cars beyond the normal 24 or possibly 48 hours allowed for loading. Therefore, potential loading delays need to be considered in determining the minimum chip-production capacity needed for a successful chipping business.

SUMMARY AND CONCLUSIONS

These analyses of chip production costs at seven hardwood sawmills show that cost structure is unique for each firm. Costs per ton at each mill are related to a combination of its average daily and annual chip output.

The information in this paper provides an objective basis for evaluating chip-producing opportunities at hardwood sawmills. The evaluation leads to an estimate of the change in total net cost to the sawmill firm per ton of chip produced. This procedure includes the change in sawmill activities altered by debarking and chipping — such as saw maintenance, log cleaning, and wood residue disposal. At the mills studied, such changes resulted in respective average cost savings of $0.42, $0.67, and $0.29 per thousand board feet of lumber produced.

Although mill selection was not intended as a survey sample of the industry, the firms included in this study form a large portion of the western Appalachian Region's combined hardwood chip-production capacity. Therefore these case studies may be representative of the mill-size range and corresponding chip-production costs for the area. To the extent that this is true, changes in saw maintenance, log cleaning, and wood-residue disposal should reflect corresponding cost changes that are applicable to this industry as a whole.

Technology and experience in debarking and chipping are sufficient to suggest that, with effective evaluation techniques available, more sawmill firms should be encouraged to examine hardwood chipping. Proper evaluation acts to narrow the range of uncertainty facing sawmill operators and may lead to increased hardwood chipping and may contribute to better use of existing installations and raw materials.

■

THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM.

II. DESCRIPTION OF SUBSYSTEM EDIT.

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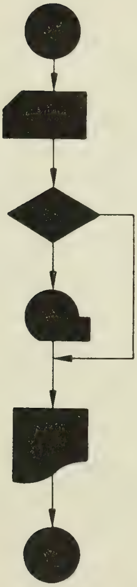

by
Robert W. Wilson Jr.
and Robert C. Peters

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RICHARD D. LANE, DIRECTOR

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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM. II. DESCRIPTION OF SUBSYSTEM EDIT.

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PREFACE

THIS paper is the second in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers — subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers — subsystem OUTPUT.

II-A. INTRODUCTION

ONE of the major projects of the U.S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

The purpose of this paper is to describe a part of the system, the subsystem EDIT, which is designed for high-speed editing of large numbers of unit records.

The editing functions are of three general kinds: checking values in each record for legality or reasonableness; generating additional values for each record; and accumulating values from each record in one-dimensional tables to produce simple summaries of information from the subsets of the records.

Each unit record is processed independently of all other records in the input file. Processing is controlled by a set of operations chosen from among those available in the program. These operations give the scope and flexibility needed to tailor the program to specific editing problems of great variety and complexity. And, although designed primarily to edit records, the ingenious user will find the program serves other purposes as well. For example, it may be used to form record-frequency distributions; to accumulate sums and sums of squares of specified values in records; to update master summary files; or to search a record file for specified sets of records.

The program is written in the standard FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 Direct Coupled System under the IBSYS Operating System with IBJOB Processor.[1] It will operate with little or no modification on other comparable systems.

Part IV in this series contains a selection of programming information that will be useful if the standard version of the program must be modified for any reason. Detailed instructions for setting up and executing jobs with the standard version are given in part III of the series. Copies of these publications and information about the FORTRAN IV source decks for the program can be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

II-B. PROGRAM OUTPUTS

The program provides four kinds of output: (1) a magnetic tape file of records that have passed successfully through all editing operations, (2) a printed list of messages, (3) printed tabulations of the information summaries for record subsets, and (4) a deck of punched cards containing the same information summary tables. The user may exercise several options with respect to all but the last of these outputs.

Ordinarily, the magnetic tape file of correct, augmented records is the primary goal and most important output of an editing job. However, in some types of problem, this output may not be required; so provision is made to suppress it (part III-C, item 161). Again, the correct output will normally be used only as input to another processing program; so provision is made to write the output file in binary mode. However, the alternative of writing the tape in binary coded decimal (BCD) mode is also available, should it be necessary to print the output. Finally, the correct record output may be punched in cards (BCD mode), but this option should be used only if the number of output records is small.

---

[1] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

Each correct output record may consist of up to 132 data fields that contain either values from the corresponding input record or values generated for the record during processing. The values are listed in the record in the same order that they are input and generated. Any format may be specified for BCD output records (part III-C, item 162).

The messages printed fall into three categories: (1) those that summarize the actual processing of the job; (2) those that signal an error in preparing the job control deck; and (3) those that describe errors detected in input records by the editing operations. Appropriate messages from the first two categories will always be printed, but the user may elect to suppress messages in the third category (part III-C, item 161). If the input record error messages are not suppressed a message will be printed for every input record in which an error is detected. The message will describe the error and will include a copy of the input record. If an input record contains more than one error only the first one detected will be identified in the message.

The printed tabulations of information summarizing sets of records are optional. Such tables are formed in the computer only if specified by the user (part III-C, item 131); and if formed, they are printed only if so specified (part III-C, item 171). If formed, the tables will always be punched in cards for use in a subsequent pass (part III-C, sec. 140). If printed up to four tables of the same length may be printed side by side on a page. The tabulation may include a table which identifies each line of output, and any table may be printed more than once.

II-C. DATA INPUTS

The data input to this program consists of a single magnetic tape file of records´to be edited. The total number of records to be processed from the file must be specified. Records may appear in any order that is convenient. The tape may be written either in binary or in BCD mode.

The input records must all have a common format but the format can be chosen to fit the problem: the input format is variable. A format specification (part III-B, item 152) must always be provided in the job control deck. Up to 132 data fields may be specified for an input record.

II-D. PROGRAM LOGIC AND PROCEDURES

The program has three primary phases that are performed in sequence: (1) the job control deck is read and checked, as far as is possible; (2) the records are processed; and (3) the end-of-pass procedures are carried out, including the printing of a job summary and the punching of special summary tables requested by the user (fig. 1). The program will not proceed to record processing until the control deck has passed all checks.

The user is concerned primarily with the second or processing phase. This phase uses the logic of unit record processing; that is, only one record is handled at a time. It is read, processed, and written out before the next record is read. The processing of any given record is independent of any other record and the sequence of records in the input file determines the sequence in which they are processed. The number of consecutive records to be processed from an input file is specified by the user. Any number up to the maximum number in the file may be processed in one program pass. Additional files can be processed only by additional passes with the program, using if necessary the updating procedures described below.

The user also specifies the maximum number of errors that can be recorded in a pass before processing is automatically halted. An unreasonably large number of errors usually signifies some undetected error in the control deck. This control allows the user to check the control deck before processing all the records. If no error is found, processing may be continued by the updating procedure; otherwise, the control deck is corrected and the pass is repeated from the beginning.

The processing of an individual record is controlled entirely by a set of 11 operations. Each operation performs a particular editing function, using the contents of specified data fields and other pertinent information. The operations contained in the program are:

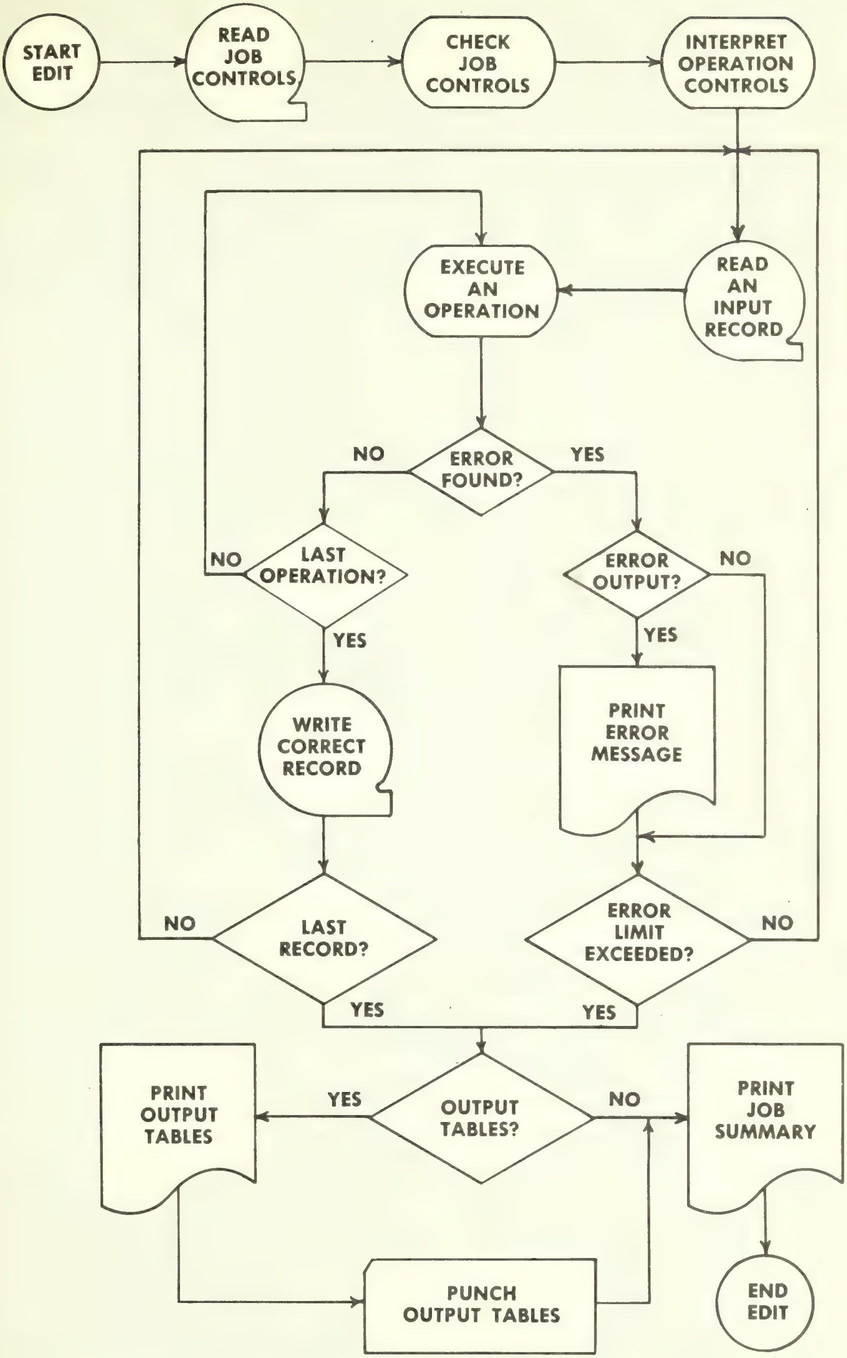


Figure 1. — A generalized flow chart of EDIT.

1. ***FLOAT.*** — The operation that converts up to nine values from fixed point to floating point numbers. The operation also allows the floating point numbers to be scaled after conversion, using division by powers of 10.

2. ***FIX.*** — The operation that converts up to nine values from floating point to fixed point numbers. The operation also allows the floating point numbers to be scaled before conversion, using multiplication by powers of 10.

3. ***LIST C (for list check).*** — The operation that checks a single value against a list of values. An input table gives the list. There are two checking options: the legal option records an error when the value is not found in a list of all values permitted; the illegal option records an error if the value is found in a list containing all values not permitted.

Any data field used in this operation must contain a fixed-point number. The input table must contain as many entries as there are values permitted (or not permitted, if the illegal option is used). Each entry contains just one of the permitted values.

4. ***CROSSC (for cross check).***—The operation that checks the consistency among up to nine values. There are two cheking options: the legal option records an error when the combination of values is not found in an input table containing all combinations of values permitted; the illegal option records an error if the combination of values is found in an input table containing all combinations of values not permitted.

All data fields used in this operation must contain fixed-point numbers. The input table must contain as many entries as there are combinations of values permitted (or not permitted, if the illegal option is used) in the data fields being checked. Each entry of the input table contains one combination of values, in specified order.

For example, assume that the following relationships must exist between the values in the first and the second data fields of a record: if the value in the first field is 1, then the value in the second field must be 1, 2, 3, 4, or 5; and, if the value in the first field is 2, 3, or 4, then the value in the second field must be 2, 3, 4, or 5; and, if the value in the first field is 5 or 6, then the value in the second field must be 6. There are 19 possible combinations of these values, so the input table must contain 19 entries, using the legal checking option. The first digit of each entry is a permitted value of the first field and the second digit is a corresponding value permitted for the second field. The input table entries for this example are: 11, 12, 13, 14, 15, 22, 23, 24, 25, 32, 33, 34, 35, 42, 43, 44, 45, 56, and 66.

Note that the input table entries are arranged so that the values are in ascending order. This arrangement must hold for any input table.

5. CROSSR (for cross range check).—The operation that checks a single value against a range. The range is selected from an input table on the basis of one other value. Actually, two checks are made: an error is recorded if the value used to select the range is not found in the input table (a list check); and, an error is recorded if the value being checked is not equal to or greater than the minimum value and less than or equal to the maximum value of the range.

Both data fields used in this operation must contain fixed-point numbers. The input table used must contain as many entries as there are values permitted for the data field used in selecting the range. Each input table entry consists of three fields: the first contains one of the values used to select the range; the second contains the minimum value of the range; and, the third contains the maximum value of the range.

For example, assume that the following relationships must exist between values in the first and the second data fields of a record: if the value in the first field is 1, then the value in the second field must fall between 1 and 13, inclusive; and, if the value in the first field is 2, then the value in the second field must fall between 18 and 62, inclusive. The input table must contain two entries: 10113 and 21862.

6. SEQUEN (for sequence check). — The operation that checks the sequence of values in a single data field from one record to the next. Either an ascending or a descending sequence may be checked for a constant increment (or decrement). An error is recorded if the increment or decrement is not constant.

Any data field used in this operation must contain a fixed-point number. The initial value of the sequence and the value of the constant are specified in calling the operation.

7. *LOGIC (for logical expression).* — The operation that determines the truth value (true or false) of a given logical expression, and executes a branch specified for that value. For the occurrence of a given truth value, one of the following actions is specified: record an error and begin processing the next record; skip a specified number of operations and continue processing the current record. For an occurrence of the alternate truth value, the action is always to execute the next operation in sequence with the current record.

All numeric values used in this operation must be fixed-point numbers. The values can be those in data fields, or they can be constants; up to two constants can be used in one logical expression.

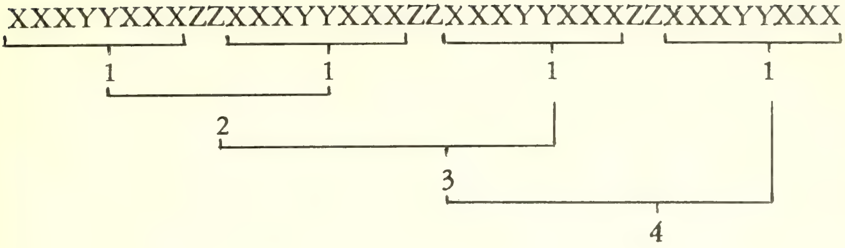
The logical expression is constructed from simple logical statements or comparisons of two values according to one of six relational operators:

EQ = equal to
GT = greater than
LT = less than
NE = not equal to
GE = greater than or equal to
LE = less than or equal to

The logical expression can contain up to four such comparisons, each associated with the others by one of three logical connectives:

AN = and
OR = or
TH = if . . . then

To determine the truth value of the logical expression, the truth values of the simple comparisons are obtained first. These values, and their logical connectives, are then scanned from left to right to obtain the truth value of the entire expression:



where —

XXX = a numeric value
YY = a relational operator
ZZ = a logical connective

The truth sets for the compound expressions involving statements "p" and "q" are:

p	q	p *AN* q	p *OR* q	p *TH* q
T	T	T	T	T
T	F	F	T	F
F	T	F	T	T
F	F	F	F	T

8. ARITHE (for arithmetic expression). — The operation that supplies a value for a data field by evaluating a given arithmetic expression containing up to eight other values (including up to two constants), and any of the following arithmetic operators:

+ = add
— = subtract
* = mulitply
/ = divide
** = raise to the power of

All values used in the operation must be floating-point numbers. The value generated is also a floating-point number. The expression is evaluated from left to right:

$$\mathrm{XXX} = \underbrace{\underbrace{\underbrace{\underbrace{\underbrace{\underbrace{\underbrace{\mathrm{XXXAAXXX}}_{1}\mathrm{AAXXX}}_{2}\mathrm{AAXXX}}_{3}\mathrm{AAXXX}}_{4}\mathrm{AAXXX}}_{5}\mathrm{AAXXX}}_{6}\mathrm{AAXXX}}_{7}$$

where

XXX = a numeric value
AA = an arithmetic operator

9. GENERA (for generate values). — The operation that supplies values for one or more data fields. The values are supplied from an input table according to a combination of other values. This operation also records an error if the combination of values is not found in the input table. If the combination is found, the corresponding generated values are moved from the input table to the record.

All data fields used in this operation must contain fixed-point numbers, and all generated values must be fixed-point numbers. The input table must contain as many entries as there are combinations of permitted values. Each input table entry contains one of these combinations followed by the corresponding generated values.

For example, assume that the permitted values in the first data field are 3, 4, 7, and 9; that when the value in the first field is 3 or 4, a value of 1 is to be generated for the second field; that when the first field contains a 7, the second field is to contain a 2; and that when the first field is 9, the second field must be 3. Since there are 4 values permitted for the first field, the input table must contain these 4 entries: 31, 41, 72, and 93.

10. CALCUL (for calculate values).—The operation that may be specially programmed to perform any unusual or complex calculations required to obtain values for data fields.

Data fields used in this operation may contain either fixed-point or floating-point numbers. No input tables may be used. The operation is programmed in FORTRAN IV, according to instructions given in part IV-A.

11. ADD. — The operation that forms an output table by summing the value in a data field, or a constant value, into a cell of the output table each time a record is processed. The particular cell in which the value is accumulated is selected by a combination of up to eight or nine other values in the record, using an input table for identification. This operation also records an error if the combination of values used to select the cell is not found in the input table. If the combination is found, a value is summed into the corresponding cell of the output table.

The values used to select the cell in the output table must be fixed-point numbers. The value to be summed into the cell must be a floating-point number. The input table must contain as many entries as there are combinations of permitted values used to select the output table cell. Each input table entry consists of one of these combinations.

* * *

In calling an operation (part III-B, sec. 120), the user gives the operation name, specifies the data fields to be used, and gives the constants or input tables (part III-B, sec. 110) required for the operation. The description of each combination is recorded on an operation-control card. Any operation may be called more than once with different arguments, but the total number of operations per record cannot exceed 100. The operations are performed in the same sequence as the operation cards appear in the control deck. Thus, the user controls the logic of record processing by the way he orders the operation cards. Logical control can be extended by use of the LOGIC operation to cause a branch during the processing of selected records.

The processing of a record will be discontinued by the detection of an error in a record. An error message will be printed and processing will go on to the next input record without completing the operations on the current record. This must be considered in constructing the logic of record processing. For example, in a case where records are to be checked for correctness and a frequency distribution of correct records is to be formed (by an ADD operation), the checking operations obviously must precede the operation that will accumulate the frequencies. Those applications in which the hierarchy of operations is important will often be complex enough to warrant the use of a flow chart in selecting and sequencing the operations.

To correct records found to be in error and add them to the output tables obtained at the end of the initial pass, provision has been made to punch out each such table (part III-B, sec. 140) in a form that can be added to the original control deck for a subsequent pass of the program with the corrected records. During this pass the corrected records are again checked and those that are correct are added to the tables that have been read in. This updating procedure can also be used with an initial pass to enter non-zero values in tables of accumulation such as might be required in an accounting or an inventory application.

II-E. CONCLUSION

In the preceding chapters program EDIT has been described as a general unit-record processor in which all data-handling functions as well as a comprehensive set of editing operations have been pre-programmed. In a given application, the actual editing of the unit records is programmed to fit the requirements of the application by defining each step in the process in terms of the pre-programmed operations and the format of the input records.

The definition of these steps and the provision of certain other information are always the responsibility of the user. The description of the job control deck in part III can be used as a checklist in assembling the description of any processing problem.

Preparing and checking the job control deck is not easy. The deck contains a great deal of detailed information about the problem, not all of which can be checked by the program prior to test runs. Consequently, while the program offers an efficient means to solve a variety of processing problems involving large amounts of data, some other means will generally be better when only small amounts of data (less than 5,000 records, say) are to be processed.

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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM.

III. OPERATION OF SUBSYSTEM EDIT.

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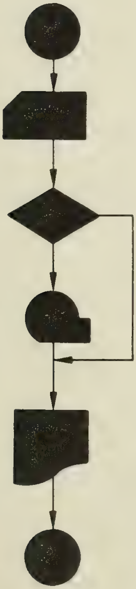

by
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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM. III. OPERATION OF SUBSYSTEM EDIT.

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PREFACE

THIS paper is the third in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers — subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers — subsystem OUTPUT.

III-A. INTRODUCTION

ONE of the major projects of the U.S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper tells about the operation of a part of the system, subsystem EDIT. Detailed instructions for solving editing problems with the standard version of program EDIT are given in the following chapters.

A general description of the program outputs, inputs, logic and procedures, which should be read before attempting to use the program, is presented in part II of this series. It is particularly important to understand how the user sets up his own processing logic by the order and content of the operation cards (sec. 120) in the job control deck.

The program was written in the standard IBM FORTRAN IV language, for use with Yale University's IBM 7094/7040 Direct Coupled Computer System under the IBSYS DCS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable systems. Part IV in this series contains a selection of programming information that will be useful if the standard version of the program must be modified for any reason.

Copies of these publications and information about the FORTRAN IV program decks can be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

III-B. CONTROL CARD FORMATS

The description and specification of an editing job is presented to the computer through a special deck of data cards referred to as the job control deck. Each card in this deck contains specific pieces of information arranged in a definite format.

In this chapter each type of control card is described. The description gives the format of the cards, the information they contain, and where appropriate, the purpose and use of the information required. Consequently, this chapter may be used both as a detailed list of instructions for coding the description of a job, and as an outline to follow in the initial stages of job specification in order that the specifications can be complete.

1. Job Control Cards (Sec. 100)

The first two cards in the control deck are the title card (item 101) and the pass identification card (item 102). They contain a descriptive job title and identification of the run within the job. The update option (columns 9-15 in item 102) may be ignored unless output tables are being formed by add operations. Both cards must always be present in the control deck (fig. 1).

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[1] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

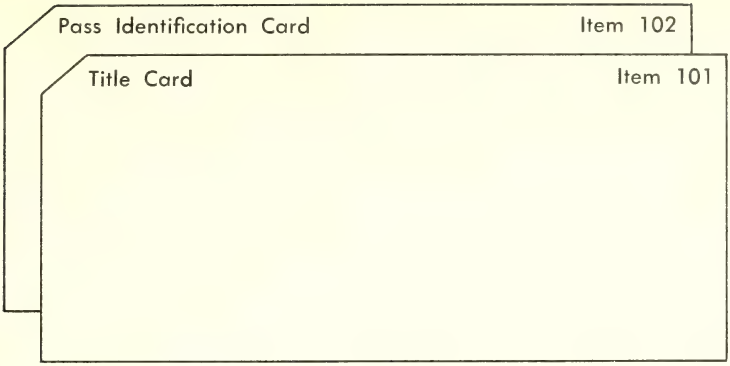


Figure 1. — Order of the job control cards in the job control deck.

TITLE CARD — ITEM 101

Columns	*Contain —*	*Explanation*
1-72	AAA . . . A	= Alphameric characters, giving a descriptive title for the job. The title will appear at the top of each page of printed output.

PASS IDENTIFICATION CARD — ITEM 102

Columns	*Contain —*	*Explanation*
1-4	PASS	= card label.
5	b	
6-7	XX	= 2 numeric characters, giving the pass identification number. The number must be right-justified in the field. It will be punched in the header cards of the punched output.
8	b	
9-15	bbbbbb	= No update tables (see sec. 140) of initial values for tables produced in add operations (see item 131) are in the control deck. The initial values of the output tables are set at zero.
	UPDATE	= Update tables of initial values are in the control deck. The initial values of the output tables are read from the UPDATE tables.

2. Input Table Cards (Sec. 110)

This section describes each type of card required in the job control deck to provide the input tables used in editing operations (see part II-D and part III-B, sec. 120).

The no input tables card (item 111) is to be used if the job does not require input tables. In this case, no other cards from this section need be used (fig. 2A).

Up to 40 input tables may be put in the job control deck and the tables may be in any order (fig. 2B). However, all tables must be placed in the control deck as a group, and the last card of the group must be the input table finish card (item 115).

Three types of card are required for each input table, and the cards for each input table must appear as a set in the control deck.

The first card of each set is the input table name card (item 112) which gives a unique name to the table and specifies the number of entries in the table.

The second card of the set is the input table format card (item 113) which describes the format of each entry in the table.

The remaining cards of each set are repetitions of the input table entry card (item 114) in which a single table entry is punched. There must be as many of these cards as there are table entries, and they must be arranged so that the entry values are in ascending order within each table.

The card following the last input table entry card of a given table must either be the input table name card for the next table, or an input table finish card.

NO INPUT TABLES CARD — ITEM 111

Columns	*Contain —*		*Explanation*
1-15	NObINPUTbTABLES	=	A control word signifying that there are no input tables in the control deck.

INPUT TABLE NAME CARD — ITEM 112

Columns	*Contain —*		*Explanation*
1-6	AAAAAA	=	6 alphameric characters, giving a unique name by which the table that follows is referenced to an operation. The user may assign any name he wishes but the name must be left-justified in the field.

7-15	bbb . . . b	= 9 blanks.
16-20	XXXXX	= 5 numeric characters, giving the number of entries in the table just named. The number must be right-justified in the field.

INPUT TABLE FORMAT CARD — ITEM 113

Columns	*Contain —*	*Explanation*
1	b	
2	X	= 1 numeric character, giving the total number of fields contained in an entry of the table. The maximum allowable number is 9.
3	b	
4	X	= 1 numeric character, giving the number of columns occupied by the first (leftmost) field of an entry in the table.
5-20	bXb . . . X	= Repetitions of columns 3-4 format, giving the number of columns occupied by the remaining fields of an entry in the table, if any.
21	(	= left parenthesis.
22-80	AAA . . . A	= Up to 59 alphameric characters ending with a right parenthesis, and containing a FORTRAN format specification (blanks not permitted) which describes the format of the entries in the table. All fields must be specified as decimal integers (I).

INPUT TABLE ENTRY CARD — ITEM 114

Columns	*Contain —*	*Explanation*
1-80	XXX . . . X	= A maximum of 9 numeric characters, giving a single table entry, according to the format given in the appropriate input table format card (item 113, columns 21-80). If the entries of a table contain 9 fields, the values for the first (leftmost) field cannot exceed 7.

INPUT TABLE FINISH CARD — ITEM 115

Columns	*Contain —*	*Explanation*
1-6	FINISH	= A control word signifying the end of all input tables. This card must always follow the last table entry card of the last input table in the control deck. It should not be used if there are no tables and the no input tables card (item 111) has been used.

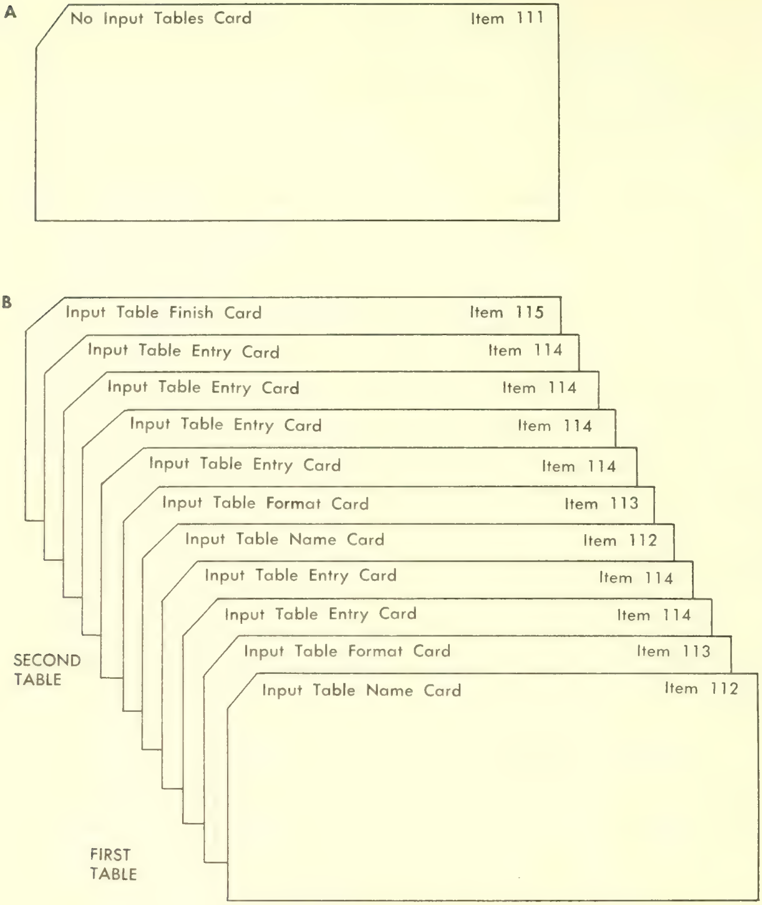


Figure 2. — Order of the input table cards in the job control deck: **A**, when the job requires no input tables; **B**, when the job requires two input tables, with two or four entries, respectively.

3. Operation Cards (Sec. 120)

The control cards described in this section are used to call or activate the editing operations (see part II-D). Consequently, there must be at least one card from this group in the job control deck to make the program operative. There may be up to 100 of these cards in the deck (fig. 3).

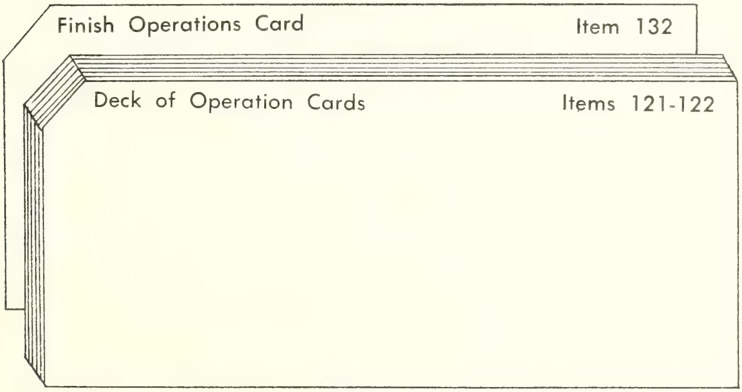
There is one type of card for each of the 11 editing operations but they have more or less common formats. In general, the cards contain the name of a particular operation, the identification numbers of the data fields to be used in the operation, and the names of input tables or values of constants to be used.

Each type of card may appear in the control deck as often as required by the editing problem (subject to the maximum number restriction). The nature of the problem also dictates the order in which the cards are placed in the deck because the operations are executed in sequence from first card to last for each input record.

The group of operation cards must always be followed in the control deck by the finish operations card (item 132) which simply signals the end of this group of cards.

It should also be noted that the values in all data fields used in the FIX, ARITHE, and ADD operations must be expressed as floating-point numbers at the time of their use. For all other operations the data field values must be expressed as fixed-point numbers. The FLOAT and FIX operations are to be used in making any conversions that are necessary.

Figure 3.—Order of operation cards in the job control deck. The deck of operation cards may contain up to 100 cards. The order of the items in the deck and number of times each one appears are dictated solely by the requirements of the job.



FLOAT OPERATION CARD — ITEM 121

Columns	*Contain —*	*Explanation*
1-5	FLOAT	= The name of the operation that will float a fixed point number according to the scale provided on the operation card.
6-7	bb	
8-11	XXXY	= Where XXX is the data field to be floated and Y is the desired number of places to the right of the decimal.
12	,	
13-51		Repetitions of the columns 8-12 format for each data field to be floated. No comma is necessary after the last data field and its scale.

FIX OPERATION CARD — ITEM 122

Columns	*Contain —*	*Explanation*
1-3	FIX	= The name of the operation which will fix a floating-point number according to the scale provided on the operation card.
4-7	bbbb	
8-11	XXXY	= Where XXX is the data field to be fixed and Y is the number of positions to the right of the decimal to be preserved from the original floating-point number.
12	,	
13-51		Repetitions of the columns 8-12 format for each data field to be fixed. No comma is necessary after the last data field and its scale.

LIST CHECK OPERATION CARD — ITEM 123

Columns	*Contain —*	*Explanation*
1-6	LISTbC	= The name of the operation that checks the value in a data field against a list of values in a table.
7	L	= Legal values are contained in the table named in columns 68-73.
	I	= Illegal values are contained in the table named in columns 68-73.
8-10	XXX	= 3 numeric characters, giving the identification number of the data field to be checked. The number must be right-justified in the field.
11-67	bbb . . . b	= 57 blanks.
68-73	AAAAAA	= 6 alphameric characters, giving the name of the input table to be used in the operation.

The name must be left-justified in the field, and must be exactly as given on the appropriate input table name card (item 112).

CROSS CHECK OPERATION CARD — ITEM 124

Columns	*Contain —*		*Explanation*
1-6	CROSSC	=	The name of the operation that checks the consistency of the values among several data fields of an input record.
7	L	=	Legal values are contained in the input table named in columns 68-73 of this card.
	I	=	Illegal values are contained in the input table named in columns 68-73 of this card.
8-10	XXX	=	3 numeric characters, giving the identification number of the first data field to be used in this operation. The number must be right-justified in the field. Up to 9 data fields may be identified in the following columns of this card for use in this operation. The numbers must be listed in the order in which the values of the data fields appear in the input table named in columns 68-73 of this card.
11-12	bb		
13-52	XXX . . . X	=	Repetitions of the columns 8-12 format, giving the identification numbers of the remaining data fields to be used in this operation.
53-67	bbb . . . b	=	15 blanks.
68-73	AAAAAA	=	6 alphameric characters, giving the name of the input table to be used in this operation. The name must be left-justified in the field, and must appear exactly as given in columns 1-6 of the appropriate input table name card (item 112).

CROSS RANGE CHECK OPERATION CARD — ITEM 125

Columns	*Contain —*		*Explanation*
1-6	CROSSR	=	The name of the operation that checks the value in a data field against a range of values determined by the value in one other data field.
7	b		
8-10	XXX	=	3 numeric characters, giving the identification number of the data field that determines the range of values to be used in the operation. The number must be right-justified in the field.

11-12	bb	
13-15	XXX	= A repetition of the columns 8-10 format, giving the identification number of the data field to be checked in the operation.
16-67	bbb . . . b	= 52 blanks.
68-73	AAAAAA	= 6 alphameric characters, giving the name of the input table to be used in the operation. The name must be left-justified in the field, and must be exactly as given on the appropriate input table name card (item 112).

SEQUENCE CHECK OPERATION CARD — ITEM 126

Columns	*Contain —*	*Explanation*
1-6	SEQUEN	= The name of the operation that checks the sequence of values in a data field from one record to the next.
7	b	
8-10	XXX	= 3 numeric characters, giving the identification number of the data field to be checked. The number must be right-justified in the field.
11-53	bbb . . . b	= 43 blanks.
54-59	XXXXXX	= 6 numeric characters, giving the initial value in the data field to be checked. The number must be right-justified in the field.
60	b	
61-66	XXXXXX	= 6 numeric characters, giving the increment or decrement between values in the data field. The number must be right-justified in the field. The number must be preceded by an arithmetic sign in the field: a (+) for increment, and a (—) for decrement.

LOGIC OPERATION CARD — ITEM 127

Columns	*Contain —*	*Explanation*
1-5	LOGIC	= The name of the operation that determines the truth value of a logical expression and uses it to select an appropriate course of action.
6-7	bb	
8-10	AAA	= 3 alphameric characters, giving the identification number of the data field or the name of the constant (see columns 54-59 and 61-66 below) that is the subject of the simple logical statement being constructed. The identification number must be right-justified in the field.

11-12 EQ = A relational operator meaning "is equal to"; or

GE = The operator meaning "is greater than or equal to"; or

LE = The operator meaning "is less than or equal to"; or

LT = The operator meaning "is less than"; or

GT = The operator meaning "is greater than"; or

NE = The operator meaning "is not equal to"; and acting as the verb in the simple logical statement being constructed.

13-15 AAA = 3 alphameric characters, giving the identification number of the data field or the name of the constant (see columns 54-59 and 61-66 below) that is the predicate of the simple logical statement being constructed. The identification number must be right-justified in the field.

16-17 AN = A logical connective meaning "and"; or

OR = The connective meaning "or"; or

TH = The connective meaning "if then"; by which the preceding statement and the simple statement following are compounded; or

bb = No logical statement follows.

18-25 AAA . . . A = Repetition of columns 8-15 formats, giving the second simple statement in the compound statement being constructed. Leave blank if there is no second statement.

26-27 AA = Repetition of columns 16-17 format, giving the second logical connective, if any.

28-35 AAA . . . A = A repetition of columns 8-15 formats, giving the third simple statement, if any.

36-37 AA = A repetition of columns 16-17 format, giving the third logical connective, if any.

38-45 AAA . . . A = A repetition of columns 8-15 formats, giving the fourth simple statement, if any.

46 b

47 T = A character meaning "true"; or

F = The character meaning "false" is the truth value of the logical statement in columns 8-45 that will alter the processing of the current input record according to the contents of columns 48-50 (see below). On an occurrence of the truth value not specified here, processing proceeds to the next operation in sequence.

48-50	bbb	= 3 blank characters meaning an error is to be recorded for the current input record; or
	XXX	= 3 numeric characters, giving the number of following operations to skip. These courses of action are taken only under the condition specified in column 47.
51-53	bbb	= 3 blanks.
54-59	XXXXXX	= 6 numeric characters, giving the value of the constant named CO1 to be used in this operation. The number must be right-justified in the field.
60	b	
61-66	XXXXXX	= 6 numeric characters, giving the value of the constant named CO2 to be used in this operation. The number must be right-justified in the field.

ARITHMETIC OPERATION CARD — ITEM 128

Columns	*Contain —*	*Explanation*
1-6	ARITHE	= The name of the operation that evaluates an arithmetic expression and stores the result in a data field.
7	b	
8-10	XXX	= 3 numeric characters, giving the identification number of the data field in which the value of the arithmetic expression is to be stored. The number must be right-justified in the field.
11-12	=b	= An equal sign and a blank character that mark the beginning of the arithmetic expression to be evaluated.
13-15	AAA	= 3 alphameric characters, giving the identification number of the data field or the name of the constant (see columns 54-59 and 61-66 below) to be used as the first value in the expression. The identification number must be right-justified in the field.
16-17	+b	= An addition sign and a blank character, or
	—b	= A subtraction sign and a blank character, or
	*b	= An asterisk representing multiplication and a blank character, or
	/b	= A slash representing division and a blank character, or
	**	= 2 asterisks representing exponentiation. This pair of characters gives the arithmetic operation to be performed with the value of the entire expression to the left of the sign and the value of the single data field or constant immediately to the right of the sign.

18-20	AAA	= 3 alphameric characters, giving the identification number of the data field or the name of the constant (see columns 54-59 and 61-66 below) to be used in the preceding arithmetic operation. The identification number must be right-justified in the field.
21-50	AAA . . . A	= Repetitions of columns 16-20 formats, giving the operation symbols and data fields or constants to be used for the remaining terms of the expression. The expression may contain a total of 8 terms.
51-53	bbb	= 3 blanks.
54-59	XXXXXX	= 6 numeric characters, giving the value of the constant named CO1 to be used in this operation. The number must be punched with a decimal point since this entire operation is performed in floating point arithmetic.
60	b	
61-66	XXXXXX	= 6 numeric characters, giving the value of the constant named CO2 to be used in this operation. The number must be punched with a decimal point.

GENERATE OPERATION CARD — ITEM 129

Columns	*Contain —*	*Explanation*
1-6	GENERA	= The name of the operation that supplies new values for one or more data fields from an input table.
7	b	
8-10	XXX	= 3 numeric characters, giving the identification number of the first data field to be used in this operation. The number must be right-justified in the field. Up to 9 data fields may be identified in the following columns of this card for use in this operation. The numbers of the data fields to be used in searching the input table named in columns 60-65 of this card must be listed first, and in the order that their values appear in that table. The last numbers listed identify the data fields for which values are to be generated.
11-12	bb	
13-52	XXX . . . X	= Repetitions of the columns 8-12 format, giving the identification numbers of the remaining data fields to be used in this operation.

53-58	bbb . . . b	= 6 blanks.
59	X	= 1 numeric character, giving the number of data fields identified in the above list, that are to be used in searching the input table used for identification.
60-67	bbb . . . b	= 8 blanks.
68-73	AAAAAA	= 6 alphameric characters, giving the name of the input table to be used as identification in this operation. The name must be left-justified in the field, and must appear exactly as given in columns 1-6 of the appropriate input table name card (item 112).

CALCULATE OPERATION CARD — ITEM 130

Columns	*Contain —*	*Explanation*
1-9	CALCUL	= The name of the operation that may be programmed (in FORTRAN IV) by the user to perform any special calculations he requires to obtain new values for data fields.

ADD OPERATION CARD — ITEM 131

Columns	*Contain —*	*Explanation*
1-3	ADD	= The name of the operation that forms an output table by summing the value in a selected data field into a selected cell of the output table each time an input record is processed.
4-7	bbb . . . b	= 4 blanks.
8-10	XXX	= 3 numeric characters, giving the identification number of the first data field to be used in this operation. The number must be right-justified in the field. Up to 9 data fields may be identified in the following columns of this card for use in this operation. The numbers of the data fields to be used in searching the input table named in columns 68-73 of this card must be listed first, and in the order that their values appear in that table. The last number listed identifies the data field to be summed into the output table (only if 54-59 blank).
11-12	bb	
13-52	XXX . . . X	= Repetitions of the columns 8-12 format, giving the identification numbers of the remaining data fields to be used in this operation.
53	b	

54-59	XXX . . . X	= Constant to be accumulated in table. Punch with decimal. If blank, the data field appearing last in the list in columns 8-52 will be summed in table.
60-67	bbb . . . b	
68-73	AAAAAA	= 6 alphameric characters, giving the name of the input table to be used for identification in this operation. The name must be left-justified in the field, and must appear exactly as given in columns 1-6 of the appropriate input table name card (item 112).
74	b	
75-80	AAAAAA	= 6 alphameric characters, giving the name of the output table to be formed in this operation. The name must be left-justified in the field. This field defines the output table. No other reference is necessary.

FINISH OPERATIONS CARD — ITEM 132

Columns	*Contain —*	*Explanation*
1-6	FINISH	= A control word signifying the end of the set of operation cards in the control deck.

4. Update Table Cards (Sec. 140)

The use of the group of control cards described in this section is optional. The cards contain job identification and summary infomation and all tables referred to in the add operation cards (item 131) of the job control deck; hence, they are not used unless the add operation is being used in the editing job. Even then, it is not always necessary that this group of cards be in the job control deck.

Ordinarily, these cards will not be used during the first pass of a set of input data through program EDIT. However, they may be used during a first pass if there is any reason that the tables should have non-zero initial values.

Normally, the update table cards will be used only on a subsequent pass of a set of input data for which editing was not completed in the first pass, either because errors were detected in some input records, or because of a premature processing halt.

Since the entire group of cards is automatically punched at the end of every processing run, the punched table output from a previous pass with a set of input data may be used as the group

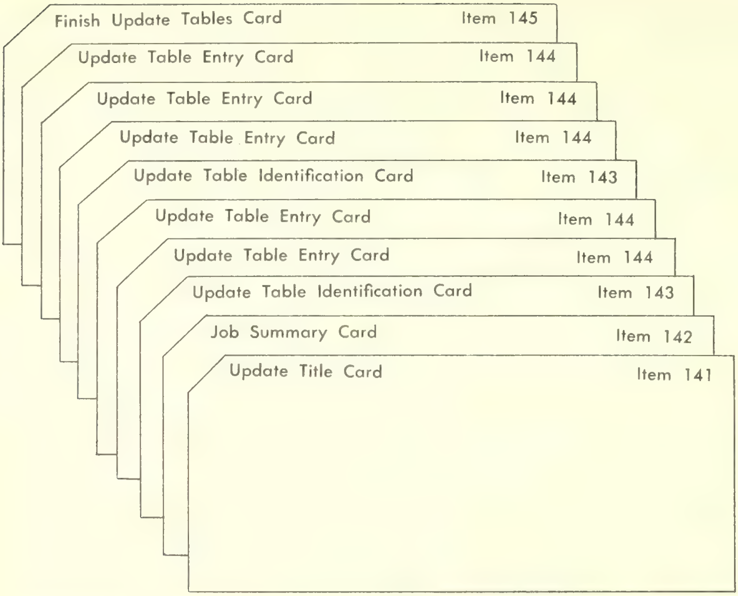


Figure 4. — Order to the update table cards in the job control deck. The entire group of cards is optional; if used, the setup must be comparable to this illustration, which shows 2 update tables with 8 and 12 entries, respectively.

of update table cards to be inserted in the job control deck for a subsequent pass (fig. 4).

UPDATE TITLE CARD — ITEM 141

Columns	*Contain —*		*Explanation*
1-72	AAA . . . A	=	72 alphameric characters, giving a descriptive title for the job. This card will generally be a duplicate of the first title card (item 101) but this is not necessary. It is used only to identify the UPDATE tables which follow it.

JOB SUMMARY CARD — ITEM 142

Columns	*Contain —*		*Explanation*
1-5	PASSb	=	Card label.
6-7	XX	=	2 numeric characters, giving the number of the pass to which the summary information applies. It is the same number that was

		given in columns 6-7 of the pass identification card (item 102) for that pass.
8-29	bNO.bRECORDSb-PROCESSED	
30-35	XXXXXX	= 6 numeric characters, giving the number of input records processed in the pass. Unless an error procedure caused a premature halt in processing, this number will be the same as that given in column 20 - 25 of the input record control card (item 151) for that pass.
36-47	bNO.bCORRECT	
48-53	XXXXXX	= 6 numeric characters, giving the number of input records that passed all editing checks.
54-63	bNO.bERROR	
64-69	XXXXXX	= 6 numeric characters, giving the number of input records that failed to pass all editing checks.

UPDATE TABLE IDENTIFICATION CARD — ITEM 143

Columns	*Contain —*	*Explanation*
1-14	THEbFOLLOWINGb	
15-19	XXXXX	= 5 numeric characters, giving the number of table entry cards for the table named below. The number is right-justified in the field.
20-35	bCARDSbAREbPASSb	
36-37	XX	= 2 numeric characters, giving the number of the pass from which the table was obtained as output. The number is right-justified in the field and is the same as the one that appears in columns 6-7 of the job summary card (item 142).
38-44	bTABLEb	
45-50	AAAAAA	= 6 alphameric characters, giving the name of the table which follows. The name is left-justified in the field, and must correspond exactly to a table name as given in columns 68-73 or 75-80 of an add operation card (item 131) of this pass.

UPDATE TABLE ENTRY CARD — ITEM 144

Columns	*Contain —*	*Explanation*
1-3	CD.	
4-8	XXXXX	= 5 numeric characters, giving consecutive identification numbers for the card. The number is right-justified in the field, and the number of the first card in any table is 1.

9	b	
10-24	XXX . . . X	= 5 numeric characters, giving the value of an entry in a table. The number is punched in E conversion. Up to 4 sequential table entries may be given in the following columns of this card.
25	b	
26-72	XXX . . . X	= Repetition of the columns 10-24 formats, giving the identification number and values of up to three additional entries in the table.
73-74	bb	
75-80	AAAAAA	= 6 alphameric characters, giving the name of the table to which these entries belong. The name is left-justified in the field, and must appear exactly as given in columns 45-50 of the update table identification card (item 143).

FINISH UPDATE TABLES CARD — ITEM 145

Columns	*Contain —*	*Explanation*
1-21	bbb . . . b	= 21 blanks.
22-27	FINISH	= A control word signifying the end of all update table cards.

5. Input Record Description Cards (Sec. 150)

The control cards in this section describe the physical condition of the input records.

The input record control card (item 151) must always appear in the job control deck. It contains the number of fields per input record, the mode in which the records are written, and the total number of records to be processed.

The input record format card (item 152) must always follow the input record control card. It contains the FORTRAN format specification for printing error messages and, if input records are written in BCD mode, for reading those records. The format continuation card (item 153) is present only if needed to complete the format specification (fig. 5).

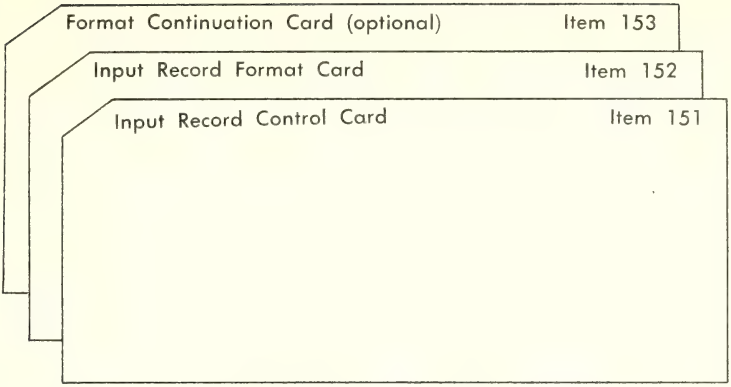

Format Continuation Card (optional)
Item 153
Input Record Format Card
Item 152
Input Record Control Card
Item 151

Figure 5. — Order of the input record description cards in the job control deck.

INPUT RECORD CONTROL CARD — ITEM 151

Columns	*Contain —*		*Explanation*
1-12	INPUTbRECORD	=	Card label.
13	b		
14-16	XXX	=	3 numeric characters, giving the number of data fields in the input records. The number must be right-justified in the field.
17	b		
18	1	=	The input data is in binary mode.
	2	=	The input data is in binary coded decimal (BCD) mode.
19	b		
20-25	XXXXXX	=	6 numeric characters, giving the total number of records to be read from the data input tape. The number must be right-justified in the field.

INPUT RECORD FORMAT CARD — ITEM 152

Columns	*Contain —*		*Explanation*
1	0	=	There is no format continuation card.
	1	=	The format specification is continued on the next card (item 153).
2	b		
3	(	=	Left parenthesis.
4-80	AAA . . . A	=	Up to 77 alphameric characters, ending with a right parenthesis, and containing a FORTRAN format specification that de-

scribes the format of the input records. This format specification is used to read BCD input data and to print error messages.

FORMAT CONTINUATION CARD (OPTIONAL)

ITEM 153

Columns	*Contain —*		*Explanation*
1-72	AAA . . . A	=	A continuation of the FORTRAN format specification described for the previous card (item 152).

6. Output Record Description Cards (Sec. 160)

The control cards in this section describe the physical conditions specified for the correct record output and the error record output.

The output record control card (item 161) gives the number of data fields to be written in the correct output records and the mode of these records. It also provides the controls concerning the recording of error records and the maximum number of errors to be allowed before termination of the job. This card must always appear in the job control deck.

The output record format card (item 162) is used only if the correct record output is to be written in the BCD mode. It contains the FORTRAN format specification for these records. The

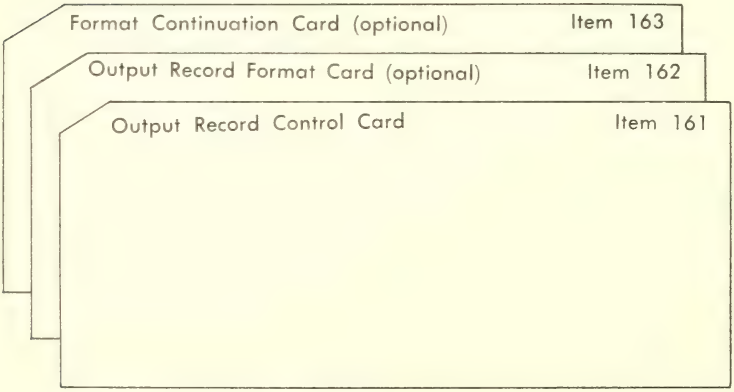

Format Continuation Card (optional)
Item 163
Output Record Format Card (optional)
Item 162
Output Record Control Card
Item 161

Figure 6. — Order of the output record description cards in the job control deck.

Format Continuation Card (item 163) is used only if needed to complete the format specification (fig. 6).

OUTPUT RECORD CONTROL CARD — ITEM 161

Columns	*Contain —*	*Explanation*
1-13	OUTPUTb-RECORD	= Card label.
14	b	
15	0	= No output of correct records.
	1	= Output correct records on tape in binary mode.
	2	= Output correct records on tape in binary coded decimal (BCD) mode.
	3	= Output correct records on punched cards (BCD).
16	b	
17-19	XXX	= 3 numeric characters, giving the total number of data fields in the correct output record. The number must be right-justified in the field. The number is the sum of the number of input fields and the number of new fields generated or calculated. It must not exceed 132.
20	b	
21-32	ERRORbOUTPUT	= Card label.
33	b	
34	0	= No error output.
	1	= All error messages are to be printed.
35	b	
36-40	XXXXX	= 5 numeric characters, giving the number of errors allowable in the run. The number must be right-justified in the field. If the number of records in which errors are detected exceeds this number, the run will be terminated and all output tables will be punched for use as UPDATE tables in a subsequent pass (see UPDATE table cards, item 140).

OUTPUT RECORD FORMAT CARD (OPTIONAL)
ITEM 162

Columns	*Contain —*	*Explanation*
1	0	= There is no format continuation card.
	1	= The format specification is continued on the next card (see item 164).
2	b	

3	(	= Left parenthesis.
4-80	AAA . . . A	= Up to 77 alphameric characters, ending with a right parenthesis, and containing a FORTRAN format specification (blanks not allowed) that describes the correct record output. This specification is needed only if a 2 or a 3 is in column 15 of the output record control card (item 161).

FORMAT CONTINUATION CARD (OPTIONAL)

ITEM 163

Columns	*Contain —*	*Explanation*
1-72	AAA . . . A	= A continuation of the FORTRAN format specification described for the previous card (item 162).

7. Output Table Description Cards (Sec. 170)

The use of the group of control cards described in this section is optional. The cards are intended primarily to describe the output format to be used if tables produced by add operations (item 131) are to be printed, but they may also be used to print any

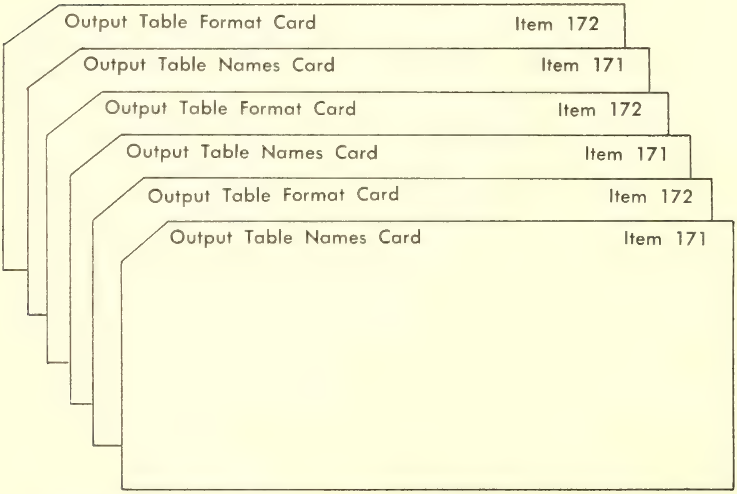


Figure 7. — Order of the output table description cards in the job control deck. Use of this group is optional. This figure illustrates a case in which three sets of output tables are to be printed.

tables used in processing. If this group of cards is not in the job control deck, no tables will be printed.

The first card in the group, the output table names card (item 171), simply lists the names of up to four tables to be printed side by side. All tables named must be the same length. The output table format card (item 172) follows. It contains a FORTRAN format specification for one line of printed table output.

This pair of cards may be repeated as often as necessary, one pair after the other, to describe all the required table output (fig. 7).

OUTPUT TABLE NAMES CARD — ITEM 171

Columns	*Contain —*		*Explanation*
1-11	TABLEbNAMES	=	Card label.
12-13	bb		
14-19	AAAAAA	=	6 alphameric characters, giving the name of the table to be printed in the first column of the table output. The name must be left-justified in the field, and must appear exactly as given in columns 68-73 or 75-80 of an add operation card (item 131). The name is used to select the table to be printed and is printed at the top of every page of table output. The names of up to four tables to be printed side by side may be listed in the following columns of this card. The order in which they are listed determines the order in which they are printed. Table names may be repeated if necessary. The tables must all be the same length.
20	b		
21-41	AAAAAA	=	Repetitions of the columns 14-20 format, giving the names of the remaining tables to be printed in the table output.

OUTPUT TABLE FORMAT CARD — ITEM 172

Columns	*Contain —*		*Explanation*
1	(	=	Left parenthesis.
2-72	AAA . . . A	=	Up to 71 alphameric characters, ending with a right parenthesis, and containing a FORTRAN format specification for a line of printed table output. No blanks are allowed in the specification. The specification should be written so that the column

for each table is centered under the table name that is printed at the top of each page. The table names are written as follows:
TABLE 1 in print positions 13-18
TABLE 2 in print positions 42-47
TABLE 3 in print positions 71-76
TABLE 4 in print positions 99-104

8. End of Job Card (Sec. 180)

The end of job card (item 181) must always be the last card of the job control deck. It simply signals the end of the job specification.

END OF JOB CARD — ITEM 181

Columns	*Contain —*	*Explanation*
1-10	ENDbOFbJOB	= A control word.

III-C. OPERATING INSTRUCTIONS

This chapter is a resume of information about program EDIT which is helpful in setting up and processing jobs. It includes a list of program restrictions on the size of a processing job; a description of the job control deck and data input setups; a summary of the use of sense switches, sense lights, and program halts; and a list of the messages which may be printed during execution.

1. Program Restrictions

The restrictions are as follows: (a) the total number of data fields in a record (input plus generated) must not exceed 132; (b) no input table entry may contain more than nine digits; (c) an input table entry containing nine 1-digit fields must not have a value greater than seven in the leftmost field; (d) the entries of a table must be arranged in ascending order; (e) the number of tables must not exceed 30; (f) the number of operations per record cannot exceed 100; and (g) the total number of table entries may not exceed 8,000.

These restrictions result primarily from the way in which the available storage capacity of the computer has been allocated to various uses in the standard version of the program. However, the program has been constructed so that the more important of these allocations can readily be changed if a problem of substantially different relative dimensions is encountered. The modification of dimensioned space is described in part IV of this series.

2. Job Control Deck Setup

The job control deck consists of all the punched cards through which processing specifications, necessary constants, tables, and other data (exclusive of the data to be processed) are entered

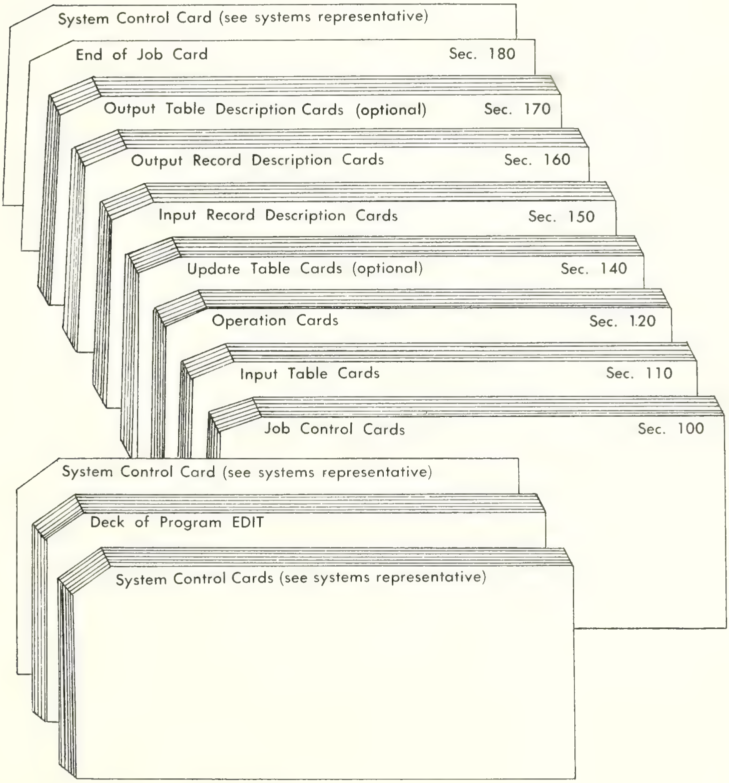

System Control Card (see systems representative)
End of Job Card Sec. 180
Output Table Description Cards (optional) Sec. 170
Output Record Description Cards Sec. 160
Input Record Description Cards Sec. 150
Update Table Cards (optional) Sec. 140
Operation Cards Sec. 120
Input Table Cards Sec. 110
Job Control Cards Sec. 100
System Control Card (see systems representative)
Deck of Program EDIT
System Control Cards (see systems representative)

Figure 8.—The job control deck setup, illustrating the kinds of cards that are necessary and the order in which they must be arranged.

into the computer. These cards, and the logical groups into which they fall, have been described in the previous chapter. The assembly of the groups of control cards to form the job control deck, as well as the placement of that deck in the monitor input deck, are shown in figure 8.

It should be noted that the monitor input deck consists of the program deck, followed by the control deck, with system control cards interspersed. The latter are not described here in detail because they vary from one computer system to another. For more information about them, see the systems representative at the computer center where the processing is to be done.

3. Input Data Setup

Data input must be in the form of a single magnetic tape file of records, each record having the same format and containing no more than 132 data fields. Multiple record files for a job must either be processed in multiple passes of the program or be put into a single record file.

The input tape file may be written either in the binary or the binary coded decimal (BCD) mode, and the tape mode must be specified in column 18 of the input record control card (item 151).

To get the input data into the required form, see your systems representative or use appropriate IBM 1401 programs.

The data input tape is not read from the monitor input unit (see below), as are the program deck and the job control deck. Consequently, it must contain only the file of input data and nothing else.

4. Tape Assignments

In the standard version of program EDIT the FORTRAN logical tape assignments are as follows:

Unit	*Use*
5	Monitor input for program deck and job control deck.
6	Monitor print for error records, other messages, and tables.
7	Monitor punch for update tables.
15	Input data in binary or BCD.
19	Output of correct records in binary or BCD.

These tape assignments can be changed to fit local conditions by loading appropriate file routines with the program. See your systems representative or the section entitled FORTRAN Files in the IBM IBJOB Processor manual, file number 7090-27.

5. Use of Sense Switches and Sense Lights

No sense switches are used in program EDIT. All sense switches will be set at normal monitor settings.

Sense light 1 is turned on when an error is found in an input record. Sense light 2 is turned on when an error is found in scanning the job control deck. No other sense lights are used.

6. Use of Program Halts

There are no halts in program EDIT.

7. Use of the Overlay Feature

The standard version of program EDIT is constructed so that the overlay feature can be used when sufficient storage is not available for the program and the data. The configuration is as follows:

Link	*Contains Subprograms*
0	MAINE, PACK, UNPACK, RESTAR
1	MAGIC
2	CONTRL
3	EDIT, LEFTAB, ALLTAB, ERCARD
4	ENDMAG

8. Messages Printed During Execution

The messages listed below are those produced by the program during execution. Each message, with its consequences, is described; and the appropriate action, if any, is indicated.

Other messages may also appear in the printed output. They will be produced by the operating system under which this program is being executed.

FIRST CONTROL CARD IS NOT
PASS IDENTIFICATION CARD

Message 1. This message occurs if the pass identification card label (columns 1-4, item 102) is incorrect. The card may be punched incorrectly, or may be out of order in the deck. Correct the error and start processing from the beginning.

CARD OUT OF SEQUENCE : TABLE AAAAAA : CARD NUMBER YYYYY

Message 2. This message is printed if the cards comprising an input table (item 114) are not in ascending order, as required. AAAAAA is the table name in columns 1-6 of item 112. YYYYY is the card number in the table. Correct the error and start processing from the beginning.

TABLE AAAAAA CONSISTING OF YYYYY CARDS HAS BEEN READ CORRECTLY

Message 3. This message is printed each time an input table has been read successfully. AAAAAA is the name of the table punched in columns 1-6 of the input table name card (item 112). YYYYY is the number of cards read for the table, taken from columns 16-20 of item 112.

TABLE NUMBER XX HAS EXCEEDED MACHINE CAPACITY

Message 4. This message is printed if the total number of entries in the input tables (item 113) is greater than available storage in the computer (see part IV C). XX is the number of the table in the input deck that was being read when available storage was exceeded. The number or size of input tables must be reduced, or the available storage must be increased before processing can be started again from the beginning.

OPERATION NAME HAS BEEN MISSPELLED

Message 5. Message prints if the operation name punched in columns 1-6 of the immediately preceding edit operation does not correspond to one of those mentioned in items 121-131. Card may be punched incorrectly or the finish operation card (item 132) may be missing. Correct and start processing from the beginning.

AN OPERAND IS NOT SPECIFIED CORRECTLY

Message 6. Message prints if the operands in the immediately preceding arithmetic operation is not from the list specified in item 128. Correct and start processing from the beginning.

THE SYMBOL AAAAAA IS INVALID

Message 7. Message prints if a relational operator or connective in the immediately preceding logic operation is not one of those allowed. AAAAAA is the symbol which is punched incorrectly. Correct and start processing from the beginning.

ILLEGAL COMBINATION OF CONNECTIVES OR OPERATIONS

Message 8. Message prints if the logic statement in the immediately preceding logic operation is not one of the types specified. Correct and start processing from the beginning.

XXXXX PROGRAM STEPS HAVE BEEN CALLED FOR YYYYY PROGRAM STEPS HAVE BEEN PROVIDED FOR — CORRECT

Message 9. Message prints when the number of operation cards (item 121-131) in the data deck exceeds the value of the variable NOPER (see part IV C). In the standard version NOPER equals 100. XXXXX is the total number of operation cards read and YYYYY is the value of NOPER. Change the number of operation cards or change the value of NOPER (see part IV C). Start processing from the beginning.

TABLE NAME CANNOT BE FOUND CHECK INPUT TABLES AND FUNCTION CARDS AAAAA

Message 10. Message prints if an input table mentioned on an ADD (item 131), GENERATE (item 129), CROSSCHECK (item 124), or CROSS RANGE (item 125) operation card cannot be found among the input table. AAAAAA is the name of the table which cannot be found. The table name may be mispunched on the operation card or the table may be missing from the control deck. Correct and start processing from the beginning.

MAXIMUM NUMBER OF INPUT TABLES EXCEEDED

Message 11. Message prints if the number of input tables (items 112-115) exceeds the value of the variable NTBLE (see part IV C). Reduce the number of input table or change the value of NOPER (see part IV C). Correct and start processing from the beginning.

INCORRECT CARD IN UPDATE TABLES

Message 12. Message prints if the job summary card (item 142) or the update table identification card (item 143) or the update title card (item 141) is missing or out of order. Correct and start processing from beginning.

UPDATE TABLE AAAAAA CANNOT BE FOUND AMONG ADD OPERATION TABLES

Message 13. Message prints if the table name punched in columns 45-50 of the update table identification card (item 143) does not agree with one of the table names punched in columns 75-80 of the add operation card (item 131). AAAAAA is the table name from the update table identification card. Correct and start processing from the beginning.

UPDATE TABLE CARDS OUT OF ORDER TABLE AAAAAA

Message 14. Message prints if the cards comprising an update table are out of sequence according to the sequence number punched in columns 4-8 of the update table entry card (item 144) or if the table name punched in columns 75-80 of the same card is not identical to the name punched in columns 45-50 of the update table identification card (item 143). AAAAAA is the table name punched in columns 45-50 of the update table identification card (item 143). Correct and start processing from the beginning.

INPUT RECORD CONTROL CARD INCORRECT

Message 15. Message prints if columns 1-6 of the input record control card (item 151) are not punched INPUTb or if the card is out of order. Correct and start processing from beginning.

ERROR IN RECORD OUTPUT CONTROL CARD CARD LABEL INCORRECT

Message 16. Message prints if columns 1-6 of the output record control card are not punched OUTPUT or if the card is missing or out of order. Correct and start processing from beginning.

ERROR ON PROGRAM STEP XXX IN THE FOLLOWING RECORD

Message 17. Message prints above the input record in which the error was found. XXX is the number of the operation card (items 121-131) in the control deck which found the error. This message only occurs if option for error output is taken on the output record control card (column 34, item 161). Correct the record and process again in a subsequent pass.

XXXXXX ERRORS HAVE OCCURRED

Message 18. Message prints if the maximum allowable number of errors is exceeded, record output control card (columns 36-40, item 161). XXXXXX is the number of errors to the point. The run is terminated and a set of update table is punched (items 142-145). Processing must be started from the beginning using the update option on the pass identification control card (columns 9-15, item 102) and altering the input record control card (item 151, columns 20-25) to conform with the number of records remaining to process. (It will be necessary to remake the input tape so that it contains only the unprocessed records.)

PASS XX PROCESSED YYYYY RECORDS OF WHICH ZZZZZ WERE FOUND CORRECT

Message 19. Message prints after all input records have been processed. XX is the pass identification number from columns 6-7 of the pass identification card (item 102). YYYYY is the total number of records processed and should be the same as columns 20-25 of the input record control card (item 151). ZZZZZ is the total number of records found correct; that is, the number of records written on the output tape or the number of cards punched depending upon the option taken in column 15 of the output record control card (item 161).

THE INVALID TABLE NAME AAAAAA HAS BEEN REQUESTED FOR OUTPUT

Message 20. Message prints if one of the names punched on the output table name card (item 171) does not correspond with the name of an input table (columns 1-6, item 112) or a table generated by an ADD operation (columns 75-80, item 131). AAAAA is the offending table name punched on the output table name card (item 171). Correct the card and start from the beginning changing columns 20-25 of the input record control card (item 151) to 000000 and using the update option (columns 9-15, item 102) with the update tables punched for the current pass (items 142-145). This will cause only the final output table to be processed.

THE TABLE AAAAA DOES NOT HAVE THE SAME LENGTH AS OTHERS REQUESTED FOR OUTPUT

Message 21. Message prints if one or more of the tables mentioned on an output table name card (item 171) is not of the same length as the other to be printed beside it. AAAAA is the name of the table taken from the output table name card. Correct the card and use the same restart procedure described for message 20.

TABLE OUTPUT CONTROL CARD INCORRECT. IT STARTS AAAAA

Message 22. Message prints if columns 1-11 of the output table name card (item 171) is not punched TABLEbNAMES. AAAAA is columns 7-11 of the offending card. Correct the card and use the same restart procedure described for message 20.

ADD TABLE DEFINED IN OPERATION XXX HAS EXCEEDED MACHINE CAPACITY

Message 23. This message is printed if the total number of entries in the input tables (item 113) plus the total number of cells occupied by ADD operation tables is greater than available storage in the computer (see part IV C). XXX is the number of the operation which defined the table which exceeded the maximum. The number or size of input table and/or ADD tables must be reduced, or the available storage must be increased before processing can be started again from the beginning.

■

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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM.

IV. INFORMATION FOR PROGRAMMERS

SUBSYSTEM EDIT.

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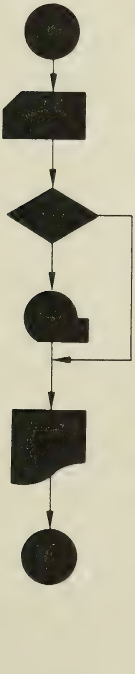

by
Robert C. Peters and
Robert W. Wilson Jr.

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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ROBERT W. WILSON, JR. took his Bachelor's degree at The Pennsylvania State University in 1947 and his Master's and Ph.D. degrees at Yale University in 1948 and 1965, respectively. He joined the U. S. Forest Service in 1948 and has worked in various research capacities for the Northeastern Forest Experiment Station. From 1961 to 1965 he was in charge of the Station's biometrics unit at New Haven, Conn. He is assigned at present to the Forest Insect and Disease Laboratory at West Haven, Conn.

THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM. IV. INFORMATION FOR PROGRAMMERS SUBSYSTEM EDIT.

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PREFACE

THIS paper is the fourth in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers — subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers — subsystem OUTPUT.

IV-A. INTRODUCTION

ONE of the major projects of the U.S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper presents information for programmers on a part of the system, subsystem EDIT. A general description of program EDIT and detailed instructions for its use in solving data-processing problems are given in parts II, and III of this series. In the following chapters will be found selected programming information that will be useful if the programs must be modified for any reason. The program write-ups and information about the program source decks may be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

The program is written in the standard IBM FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 Direct Coupled System under the IBSYS DCS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable sytems. The main requirements for a machine on which to operate the standard version of the program are a 32K word core, a minimum of 36 bits per word, binary arithmetic capability, and 5 tape drives or equivalent input/output devices.

---

[1] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

IV-B. USE OF THE CALCULATE OPERATION

The standard version of program EDIT provides a dummy subroutine named CALCUL. This dummy subroutine may be replaced by another of the same name programmed in FORTRAN IV to generate values for new data fields in each record, or to change the values in existing (input) data fields. The subroutine has the following calling sequence and DIMENSION statement:

```
 SUBROUTINE CALCUL (NDATA, PDATA, KKVAR)
  DIMENSION NDATA(KKVAR), PDATA(KKVAR),
1   FDATA(27), FREOUT(27), KTITLE(12),
 COMMON FDATA, FREOUT, KTITLE, ISTEP
```

The arrays NDATA and PDATA contain the data vector (the unit record, as stored in the computer). In the standard version of program EDIT, both arrays are 132 cells in length. To retrieve or to store information, the user must reference either PDATA or NDATA by appropriate data-field identification numbers. If the information is a fixed-point quantity, the name NDATA is used. If it is a floating-point quantity, the name PDATA is used.

For example, the following subroutine adds the values in data fields 1 and 2, and stores the resulting value in data field 27; and it divides the value in data field 101 by the value in data field 11, and stores the resulting value in data field 15:

```
 SUBROUTINE CALCUL (NDATA, PDATA, KKVAR)
  DIMENSION NDATA(KKVAR), PDATA(KKVAR),
1   FDATA(27), FREOUT(27), KTITLE(12),
 COMMON FDATA, FREOUT, KTITLE, ISTEP
 NDATA(27) = NDATA(1) + NDATA(2)
 PDATA(15) = PDATA(101)/PDATA(11)
 RETURN
 END
```

The first (add) arithmetic statement illustrates an operation done entirely in fixed-point arithmetic. The data fields in the right-hand side of the statement must have been read as fixed-point numbers or, if read as floating-point numbers, must have been converted to fixed point by the FIX operation. The second (divide) arithmetic statement illustrates an operation done entirely in floating-point arithmetic. The data fields in the right-hand side of the statement must have been read as floating-point numbers or, if read as fixed-point numbers, must have been converted to floating point by the FLOAT operation.

The variable ISTEP is the current program step. If more than one calculate operation is used, ISTEP can be used to branch to the appropriate part of the calculate routine.

IV-C. MODIFICATION OF DIMENSIONED SPACE

The standard version of program EDIT carries restrictions on both the dimensions and the overall size of problem that can be handled in a single processing run. These restrictions are a result of the manner in which dimensioned space has been allocated (table 1) and the total space available in a given operating system. The program has been written so that all modifications of dimen-

Table 1. — Summary of dimensioned-space restrictions and associated program variable and arrays

Item	Restriction	Variable	Arrays
Maximum number of cells in all input and output table entries	8,000	NDIMEN	ZIMP, IMP
Maximum number of fields/record	132	KKVAR	PDATA, NDATA
Maximum number of input and output tabes	30	NTBLE	NTAB, PNTAB
Maximum number of program operations	100	NOPER	NOVAR, NCONST, NAME, PNAME, CONST, IPROG

sioned space can be made in the subprogram called MAINE. No other parts of the program need be touched for this purpose. The use of dimensioned space and the means of changing dimensions are discussed in detail below.

Number of Data Fields per Input Record

In the standard version of program EDIT, up to 132 data fields can be used for input and output. To change this maximum the following steps must be taken:

1. In the subprogram MAINE, the variable named KKVAR must be set to the desired maximum value.
2. In the subprogram MAINE, the DIMENSION statement must be changed so that the dimension of arrays PDATA and NDATA equal the desired maximum value.

Number of Program Operations

In the standard version of program EDIT, up to 100 operations can be used. To change this maximum, the following steps must be taken:

1. In the subprogram MAINE, the variable named NOPER must be set equal to the desired maximum value.
2. In the subprogram MAINE, the DIMENSION statement must be changed so that the first dimension of arrays NOVAR, NCONST, NAME, PNAME, and CONST, equals the desired maximum value. The dimension of array IPROG must also equal the desired maximum value.

Number of Input and Output Tables

In the standard version of program EDIT, up to 30 input and output tables are allowed. To change this maximum the following steps must be taken:

1. In the subprogram MAINE, the variable named NTBLE must be set to the desired maximum value.
2. In the subprogram MAINE, the DIMENSION statement must be changed so that the first dimension of arrays NTAB and PNTAB equal the desired maximum value.

Number of Cells in All Input and Output Tables

In the standard version of program EDIT, up to 8,000 locations are available for storing all input and output tables. To change this maximum the following steps must be taken:

1. In the subprogram MAINE, the variable named NDIMEN must be set to the desired maximum value.
2. In the subprogram MAINE, the DIMENSION statement must be changed so that the dimension of arrays, ZIMP and IMP equal the desired maximum value.

If the space required for the input and output table specified in a given control deck exceeds 8,000 locations, message 4 or message 23 (see part III-C) will be printed during the reading of the control deck and processing will halt. The space required can be computed as follows:

$$\sum_{i=1}^{M} (IT_i) + \sum_{j=1}^{N} (ADD_j)$$

Where

M = Total number of input tables.

IT_i = Total number of entries in the ith input table.

N = Total number of output tables (tables defined in an ADD operation).

ADD_j = Total number of cells in the jth output table (tables defined in an ADD operation).

IV-D. PROGRAMMING FEATURES

The following information will be helpful to programmers who plan to modify the standard version of program EDIT for use on other computers or under other operating systems.

Tape Assignments

In program EDIT the FORTRAN logical tape assignments are as follows:

Unit	*Use*
5	Monitor input for program deck and job control deck.
6	Monitor print for error records, other messages, and tables
7	Monitor punch for update tables.
15	Input data in binary or BCD.
19	Output of correct records in binary or BCD

These tape assignments can be changed to fit local conditions by loading appropriate file routines with the program. See your systems representative or the section entitled FORTRAN files in the IBM IBJOB processor manual, file number 7090-27.

Use of Sense Switches and Sense Lights

No sense switches are used in program EDIT. All sense switches will be set at normal monitor setting.

Sense light 1 is turned on when an error is found in an input record. Sense light 2 is turned on when an error is found in scanning the job control deck. No other sense lights are used.

Use of Program Halts

There are no halts in program EDIT.

Use of the Overlay Feature

The standard version of the program is constructed so that the overlay feature can be used when sufficient storage is not available for the program and the data. The configuration is as follows:

Link	*Contains Subprograms*
0	MAINE, PACK, UNPACK, RESTAR
1	MAGIC
2	CONTRL
3	EDIT, LEFTAB, ALLTAB, ERCARD
4	ENDMAG

Bit Manipulation

The standard version of program EDIT uses 36-bit fixed-point words. Some input tables (those used in the cross check, cross range check, generate, and add operations) are stored by packing several fields into a single word. Some operation controls (those for FIX, FLOAT, LOGIC, and ARITHE) are stored by packing data-field identification numbers and operation options into the same word.

Words are packed and unpacked by the use of binary arithmetic. The program will not operate on a machine that uses either a larger or smaller number of bits in fixed-point operations unless the shift constants that are used to pack and unpack are changed to correspond with the number of bits per word in the particular machine.

Subprogram Names and Functions

MAINE.	The main calling sequence of program EDIT. It sets array dimensions; and calls MAGIC, CONTRL, EDIT, and ENDMAG — in that order.
MAGIC.	Reads all input table and operation cards. Checks for consistency and sets up necessary information for using each operation called.
CONTRL.	Reads update table (if present) and all control cards containing input and output record description cards. Sets up all necessary information for input/output.
EDIT.	Processes all input data according to operation described in control deck.
ENDMAG.	Reads all table output control cards and prints any table requested.
PACK.	Packs each field in a table entry with a 36-bit word. Called by EDITM and MAGIC.
ERCARD.	Writes out records which are in error.
LEFTAB.	Searches in IMP, ZIMP, array when leftmost table field is the argument.
ALLTAB.	Searches table in IMP, ZIMP array when entire entry is used as an argument.
UNPACK.	Unpacks a 36-bit word composed of a packed data field or a table entry.
RESTAR.	Punches out ADD tables (for restart or update) at end of processing, or if number of errors is greater than expected.
CALCUL.	A dummy subroutine which is called by the calculate operation. It may be programmed by the user to perform any record processing operations not provided for by the other program operations.

Important Arrays and Variables

The following are the principal arrays and variables used in program EDIT:

Array	*Dimension*	*Description*
NW, W	9	Fixed and floating-point working storage
NPSTEP	1	Total number of program operations.
ISTEP	1	The index or identification number (sequential) of the program operation currently being executed.
IVAR	1	The number of input data fields.
NTAB, PNTAB	NTBLE x 15	Indexing information for the named tables; where NTBLE is the number of input tables and the second dimension locations are used as follows: 1 = index of the first table value in IMP. 2 = index of the final table value in IMP. 3 = index of table mid-point. 4 = index of first quartile. 5 = index of third quartile. 6-14 = the number of positions, in octal, occupied by each field of a table entry. 15 = the number of fields in a table entry.
CVT	8	Field widths in a table entry, in bits.
FMT	28	Working storage for general format specifications.
NWORK	9	Working storage.
IPROG	NOPER	Identification number of the program operation used in each program step.
NOVAR	NOPER x 10	Identification numbers of each data field used in each program step, in order listed on operation cards.
NCONST CONST	NOPER x 2	Value of the constant used in each program step, if any. The value referred to as CO1 on the operation card is stored in the first location of the second dimension, and CO2 is stored in the second location.
NAME, PNAME	NOPER x 4	Identification of input tables used in each program step, if any; where the locations of the second dimension are used as follows: 1 = the identification number of the first table used in the program step. 2 = the identification number of the second table used in the program step. 3 = the alphameric name of the first table. 4 = the alphameric name of the second table.
FDATA	27	Storage for the read-in format specification for input data and/or error output.
IMP, ZIMP	NDIMEN	Storage array for all input and output tables.
NDATA, PDATA	KKVAR	Storage array for all data fields (input and generated) of the unit record currently being processed.
IWIDTH, PWIDTH	13	Storage array for output-table scale factors.
FREOUT	27	Storage array for correct record output format specification.

KTITLE	12	Storage array for the read-in title for all printed output.
NMODE	1	Number identifying the mode in which the input data is written: 1 equals binary; 2 equals BCD.
NTVAR	1	Total number of data fields output for a correct record.
NCHAR	1	Number identifying the output options: 1 = no correct record output. 2 = correct record output written in binary mode. 3 = correct record output written in BCD mode. 4 = correct record output punched.

■

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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM.

V. DESCRIPTION OF SUBSYSTEM TABLE.

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by
Robert W. Wilson Jr.
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1967
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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RICHARD D. LANE, DIRECTOR

PREFACE

THIS paper is the fifth in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers — subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers — subsystem OUTPUT.

V-A. INTRODUCTION

ONE of the major projects of the U.S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper describes a part of the system, subsystem TABLE, that is designed specifically to reduce large amounts of sample data to tables of statistics for the samples. In turn, sample summary output, is designed for use as input to program OUTPUT (see part VIII of this series) to produce tables of statistics for the sampled populations.

The principal value of the program lies in its versatility. While applying a standard, straightforward procedure to the reduction of data, it provides a very great measure of freedom in fitting both inputs and outputs to the requirements of particular data-reduction problems. Within the context of the program, the origin of the input data is immaterial; a data set that is to be processed may be sample data, but it need not be. The data set is simply a collection of values for one or more attributes of one or more objects (sampling units) that are to be reduced to tables of statistics that characterize the set. Similarly, the output tables may summarize any aspect of the data set. Several different tables, each representing all or a selected part of the input data, may be used to form these summaries. And, in order that both the inputs and the outputs may be variable, the details of the procedures by which one is converted to the other are also variable. Consequently, the program can be applied to a wide variety of data-reduction problems.

The program is written in the standard FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 Direct Coupled System under the IBSYS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable systems.

Part VII in this series contains a selection of programming information that will be useful if the standard version of the program must be modified for any reason. Detailed instructions for setting up and executing jobs with the standard version are given in part VI. Copies of these publications and information on the FORTRAN IV source decks for the program can be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

V-B. PROGRAM OUTPUTS

The primary outputs from the program are sets of statistical tables. One set of output tables is produced for each set of sample input data. An output set may consist of up to 40 two-dimensional tables. No table in the set may have more than 50 rows and 50 columns, including the row and column totals that are formed automatically for every table.[2]

The content of the tables in an output set depends entirely upon the demands of the particular application. Any attribute of the sampling units in a data set (see part V-C) can be summarized by categories determined from other sampling-unit attributes (see part V-D).

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[1] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

[2] There is also an overall restriction on the total number of cells in a set of output tables which is explained in part VII-C.

In addition, there is a choice of statistics to be provided for every cell of each table in the output set. The choices are:[3]

1. Simple sums over sampling units.
2. Means over sampling units.
3. Means and their variances over sampling units.
4. Means, their variances, and their covariances with the grand mean over the sampling units (for use when the data set summaries are to be used to make ratio estimates).

All output sets from a program run are written in a single magnetic tape file of binary records for rapid transmission to program OUTPUT,[4] in which the tables are labeled and printed as population statistics after appropriate weighting and summing. For the purpose of debugging the job control deck, the alternative of printing the tables in block form as BCD records is also available. No binary tape is written in this option.

During execution, the program prints a job summary consisting of messages of three types: those that identify errors in the job control deck that have halted execution, those identifying errors in input records (or the job control deck) that cause the record to be deleted but processing to continue, and those that signal successful reading of the job control deck and identify the data sets and numbers of sampling units that have been processed.

V-C. DATA INPUTS

The data input to the program consists of a single magnetic tape file of ordered unit records. Each record in the file must have exactly the same format as every other record. The file contains the data from sets of observed sampling units. Just how the sampling units are represented by the unit records depends upon the characteristics of the particular problem. The key is the way in which the field observations were made.

If all attributes were actually observed on the sampling unit as a whole (a plot, for example), the sampling unit observation would consist of a single value for each attribute. The sampling unit observation could then be represented by a single unit record.

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[3] These options, and the computations carried out for each, are explained in detail in part VII-F.

[4] The format of the output sets is described in detail in part VII-E.

If, on the other hand, all attributes were observed on subdivisions of the sampling unit (on trees in the plot, for example), then there would be several values for each attribute. In this case, one unit record would be required to represent each observed value of the set of attributes, so the sampling unit as a whole would be represented by a set of unit records equal in number to the number of subdivisions on which observations were made.

Generally, attributes of both kinds are observed on sampling units. In this case, there must still be a unit record to represent each subdivision observed, but the unit record format must also provide for entry of the single-valued attributes observed on the sampling unit as a whole. These values are repeated in every unit record of the set representing the sampling unit.

An additional possibility arises if attributes are actually observed on the sampling unit as a whole, on subunits of the sampling unit, and on subdivisions of the subunits. This is simply an extension of the previous case. The unit-record format must provide for recording the values of all three kinds of attributes. There will be one unit record representing each observed subdivision of the subunits. The values of attributes observed on the subunits will be repeated in each record of the subset representing the subunit; and, as before, the values of attributes observed on the sampling unit as a whole will be repeated in each record of the whole set representing the sampling unit.

In summary then, the individual unit record always represents the least subdivision of a sampling unit that has been directly observed, whatever that may be. The standard version of the program allows up to 160 unit-records in the sets representing sampling unit sets. The unit records must have a common format, and appropriate values for each of up to three kinds of attributes actually observed in a sampling unit must be recorded in every unit record. There is no provision for header cards of any kind.

The order of the unit records in the input file also depends upon the characteristics of the problem. The unit records must always be ordered by subunits, if any, within sampling units. In turn, the sampling unit sets must always be ordered into data sets. The significance of the data set is that it contains all the data required to make one set of output tables. What the data set represents in terms of the population that has been sampled depends upon the methods of sampling and of compilation that are employed. In stratified sampling, it will represent a sampling stratum. In other types of sampling, it will generally represent any kind of geographical or other unit for which output tables of statistics are required. Any number of data sets may be contained in the input file.

If required by the problem, the data sets themselves may be ordered into groups; and these groups, in turn, into still larger groups. For example, if stratified sampling has been employed in each of several survey units covering the population sampled, then the data sets must be ordered by survey unit. However, it must be remembered that all data sets processed in a single production run are subject to the same set of processing rules.

V-D. PROGRAM LOGIC AND PROCEDURES

The program consists of seven principal phases or steps connected in a simple and straightforward manner (fig. 1). The first step simply reads and stores in the computer all of the control information contained in the job control deck (part VI-C).

The second step reads a set of unit records representing a sampling unit and stores all of the data in blocks, according to the kind of attribute represented in each data field (see part V-C and part VI-C, sec. 330). Consequently, all input data for a sampling unit is available throughout the processing of that sampling unit.

The third step executes the CALCUL subroutine (part VII-B). This step is provided expressly to permit the calculation of data field values from information in more than one unit record of the sampling unit set, since this kind of operation cannot be performed in a unit-record editing process.

The fourth step produces the facsimile output tables at the sampling-unit level. This key step in the compilation process will be discussed in some detail below.

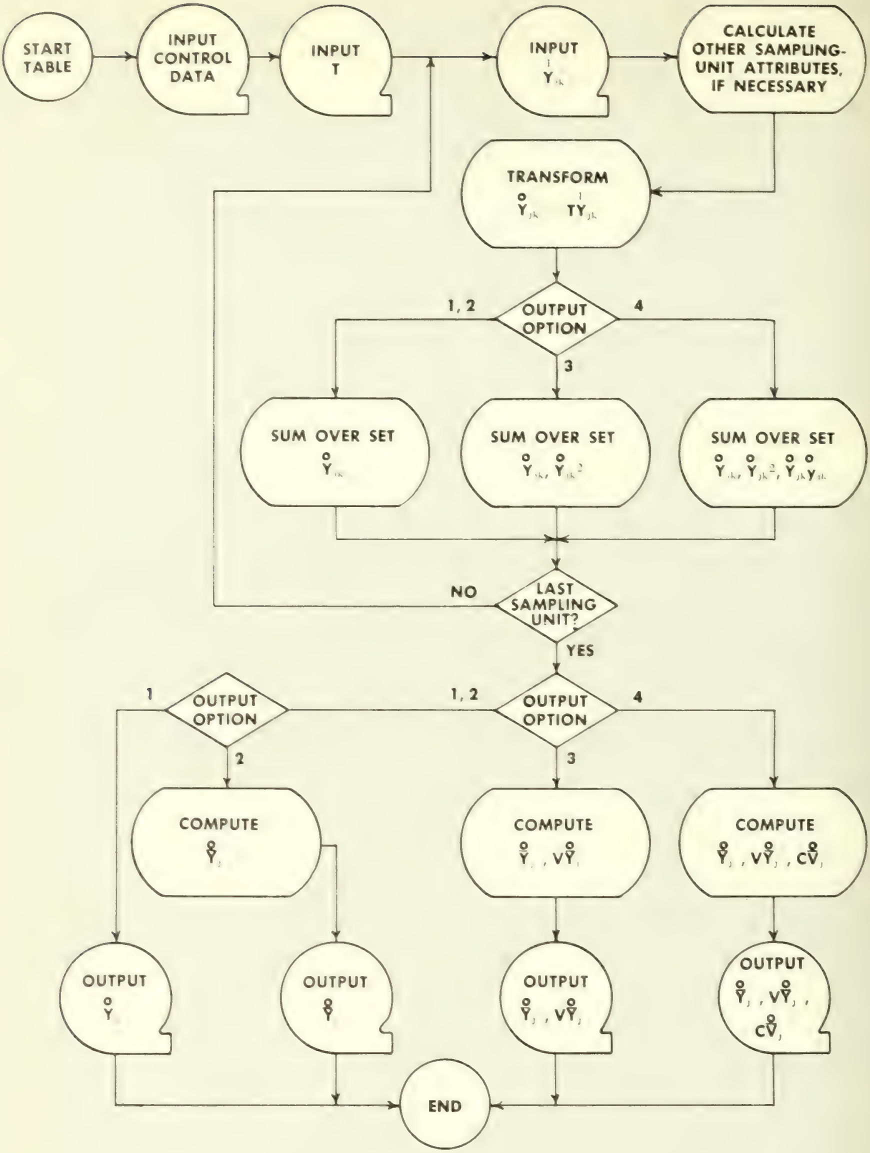
START TABLE
INPUT CONTROL DATA
INPUT T
INPUT $\overset{1}{Y}_{jk}$
CALCULATE OTHER SAMPLING-UNIT ATTRIBUTES, IF NECESSARY
TRANSFORM $\overset{o}{Y}_{jk}$ $\overset{1}{TY}_{jk}$
OUTPUT OPTION
1, 2
4
3
SUM OVER SET $\overset{o}{Y}_{jk}$
SUM OVER SET $\overset{o}{Y}_{jk}, \overset{o}{Y}_{jk}^2$
SUM OVER SET $\overset{o}{Y}_{jk}, \overset{o}{Y}_{jk}^2, \overset{o}{Y}_{jk}\overset{o}{y}_{jk}$
LAST SAMPLING UNIT?
NO
YES
OUTPUT OPTION
1
2
OUTPUT OPTION
1, 2
3
4
COMPUTE $\hat{\overset{o}{Y}}_j$
COMPUTE $\hat{\overset{o}{Y}}_j$, $V\hat{\overset{o}{Y}}_j$
COMPUTE $\hat{\overset{o}{Y}}_j$, $V\hat{\overset{o}{Y}}_j$, $C\hat{\overset{o}{V}}_j$
OUTPUT $\overset{o}{Y}_j$
OUTPUT $\hat{\overset{o}{Y}}$
OUTPUT $\hat{\overset{o}{Y}}_j$, $V\hat{\overset{o}{Y}}_j$
OUTPUT $\hat{\overset{o}{Y}}_j$, $V\hat{\overset{o}{Y}}_j$, $C\hat{\overset{o}{V}}_j$
END

Figure 1. — Generalized flow chart of TABLE.

The fifth step adds the completed sampling-unit tables to the output tables being accumulated for the data set; and if required, also adds tables of squares and of cross-products (of cells with totals) to special data set tables used to compute variances and covariances.

Steps two to five are repeated until every sampling unit in the data set has been processed. Then, the sixth step computes the required statistics for each output table from the sums that have been accumulated. The tabulated statistics are written on magnetic tape in binary mode (or printed, if the debugging output option has been taken) in the seventh and final step.

If there are additional data sets to be processed, the program then returns to step two and the cycle is repeated for each successive set.

The formation of final output tables begins with the formation of facsimile output tables for each input sampling unit, in sequence. The formation of these tables is governed entirely by a general table-making procedure provided in the program; in conjunction with information about the relationships between sampling unit data and output tables in a given application that is conveyed to the program in the job control deck.[5]

The general procedure (fig. 2) provides that each observed value of a given attribute[6] is summed (entered) into a given fac-

---

[5] The process of forming the facsimile output tables for the sampling units is similar in concept to a matrix transformation:

$$\overset{O}{Y} = T \overset{I}{Y}$$

where

$\overset{O}{Y}$ = a given two-dimension facsimile output table in which an input attribute is tabulated according to the values of two other attributes;

T = the transform that controls the process, consisting of the general table-making procedure and the control information for a given job; and

$\overset{I}{Y}$ = a two-dimension array of sampling unit input in which the data are tabulated according to observation (rows) and attribute (columns).

[6] The number of entries of a given attribute per sampling unit depends upon the kind of attribute and the number of subdivisions of the sampling unit on which it was observed (see part V-C). If the attribute was observed on the sampling unit as a whole, it has only one value, so only one entry is made in the appropriate facsimile tables. If the attribute was observed on a subdivision of a sampling unit, there will be as many values (and as many entries in the table) as there were subdivisions of the sampling unit. The general procedure automatically enters each observed value of an attribute, using information about the attribute classification furnished with the input record description in the control deck (part VI, sec. 330).

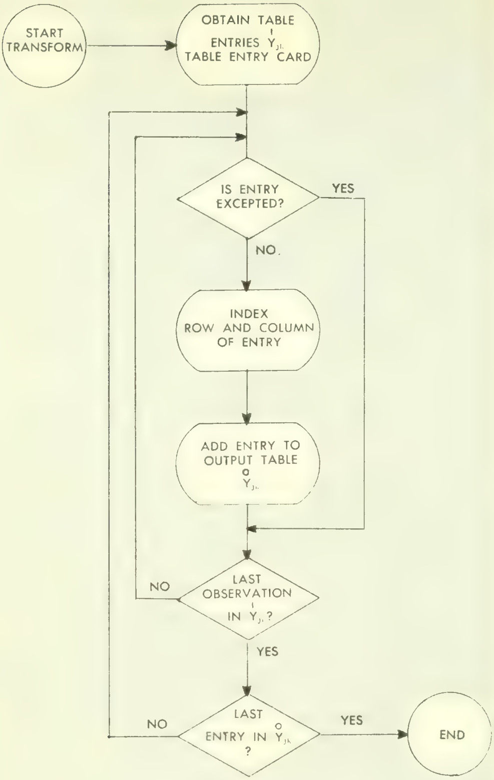
START TRANSFORM
OBTAIN TABLE ENTRIES $Y_{ji.}^{i}$ TABLE ENTRY CARD
IS ENTRY EXCEPTED?
YES
NO.
INDEX ROW AND COLUMN OF ENTRY
ADD ENTRY TO OUTPUT TABLE $Y_{j..}^{o}$
NO
LAST OBSERVATION IN $Y_{ji.}^{i}$?
YES
NO
LAST ENTRY IN $Y_{jk.}^{o}$?
YES
END

Figure 2. — Flow chart of the transform operations in TABLE.

simile table in a particular row and column (location), unless conditions are specified under which certain values of the attribute are not to be entered. The procedure also provides that up to 4 attributes may be entered in a given table. The general procedure can form almost any kind of tabulation of sampling unit data.

The information provided in the control deck (part VI-C, sec. 320) defines the particular set of output tables required. For each output table, the following information is given:

1. A short, unique name by which the output table can be identified.
2. The dimensions (number of rows and number of columns) of the table.

3. The attributes in the sampling unit data that are to be summed into the table. The values of these attributes must be expressed as floating-point numbers.
4. The attributes in the sampling unit data that determine the row and the column (location) in the output table into which each value of the entry attribute is to be summed. The values of these attributes must be expressed as fixed-point numbers.
5. The operations (and input tables, if any) by which values of the location attributes are converted to row and column indexes; chosen from among the five operations that are available in the program:
    (a) LIST, the operation that defines an index as the position in a list occupied by a given value of a location attribute. An input table contains the list of all values the given attribute is permitted to assume. For example, assume the following relationships between the values of a location attribute and the rows of an output table into which an entry is to be made: when the value is 1, the entry is in the second row; when the value is 2, the entry is in the third row; when the value is 4, the entry is in the fourth row; and, when the value is 6, the entry is in the first row. Because there are four possible values of the location attribute in one-to-one correspondence with a row index, there must be four entries in the input table: 0006, 0001, 0002, and 0004.
    (b) RANGE, the operation that defines an index position in a list occupied by a range of values that contains a given value of a location attribute. An input table contains the list of ranges that cover all possible values for the given location attribute.

    For example, assume the following relationships between the values of a location attribute and the columns of an output table into which an entry is to be made: when the value of the location attribute is less than 50, the entry is to be made in column 1; when the value lies between 50 and 73, inclusive, the entry is to be made in column 2;

and, when the value lies between 74 and 99, inclusive, the entry is in the third row. There must be three entries in the input table:

00000049, 00500073 and 00740099

(c) LOOKUP, the operation that defines an index as the value in one list of values whose position corresponds to the position in another list occupied by a given value of a location attribute. An input table provides both lists. For example, assume the following relationships between the values of a given location attribute and the rows of an output table in which an entry is to be made: when the value is 1 or 7, the entry is in the first row; when the value is 2, 3, or 4, the entry is in the second row; and, when the value is 5 or 6, the entry is in the third row. Since seven values of the location attribute are permitted, there must be seven entries in the input table:

00010001, 00020002, 00030002, 00040002,
00050003, 00060003, and 00070001.

(d) EQUATE, the operation that defines an index as equal to a given value of a location attribute. No input table is required.

(e) CONST, the operation that defines an index as equal to a given constant. No input table is required but the constant must be specified along with the operation name.

6. The conditions under which a value of an entry attribute is not to be summed into a given facsimile output table. These conditions are referred to as exceptions. Each condition requires the specification of an attribute, a constant, and a relational operator. The exception (no entry) occurs whenever a value of the attribute bears the specified relation to the constant. Any number of conditions may be applied to any entry attribute providing that the total number specified in the control deck does not exceed 150.

I-E. CONCLUSION

The foregoing chapters have described how program TABLE is designed to carry out a general data-reduction process and to incorporate a great many variations in detail automatically. This design makes the program applicable to many different data-reduction problems; but, its very flexibility means also that it cannot provide a fully automatic solution to any problem.

The user always has the responsibility for preparation of the job control deck in which the particulars of a given problem are specified. The description of the deck in part VI can be used as a check list in assembling the minimal information required; but successful application of the program demands, in addition, a thorough knowledge of the problem including the end-use of the results and the origins of the data.

It will be found that the preparation and checking of the job control deck is not easy. The deck contains a great deal of detailed information about the problem, not all of which can be checked by the program prior to test runs. Consequently, while the program offers an efficient means to solve a variety of problems involving large amounts of data or extensive tabulations of data, some other means will generally be better for simpler problems.

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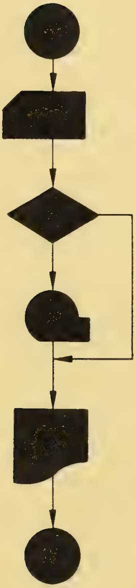

by
Robert C. Peters and
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U. S. FOREST SERVICE RESEARCH PAPER NE-74
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VI-A. INTRODUCTION

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A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper tells about the operation of a part of the system, program TABLE, which is specifically designed to reduce large volumes of sample data (data sets) to tables of statistics for the samples. The output of these sample summaries, in turn, is designed for use with program OUTPUT, part VIII of this series, to produce equivalent tables of statistics for the sampled populations. Detailed instructions for solving data-reduction problems with the standard version of the program are given in the following chapters.

A general description of the program outputs, inputs, logic and procedures is presented in program TABLE, part V of this series. The material covered in the general description should be thoroughly digested before attempting to use the program. It will also be helpful to read the general description of program OUTPUT before proceeding to use this program.

The program is written in the standard IBM FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 Direct-Coupled System under IBSYS DCS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable systems. Part VII of this series contains a selection of programming information that will be useful if the standard version of the program must be modified for any reason.

Copies of these program write-ups and information on the FORTRAN IV program decks may be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

VI-B. CONTROL CARD FORMATS

The description and specification of a table-compilation job is presented to the computer through a special deck of data cards referred to as the job control deck. Each card in this deck contains specific pieces of information arranged in a definite format.

In this chapter each type of control card is described. The description gives the format of the cards, the information they must contain; and where appropriate, the purpose and use of the required information. Consequently, this chapter may be used both as a detailed list of instructions for coding the description of a job, and as an outline to follow in the initial stages of job specification in order that the specifications be complete.

1. Job Control Cards (Sec. 300)

The first two cards in the control deck are the title card (item 301) and the output option card (item 302). They contain the job identification and the general instructions concerning the kind of output required. Both cards must always be present (fig. 1).

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[1] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

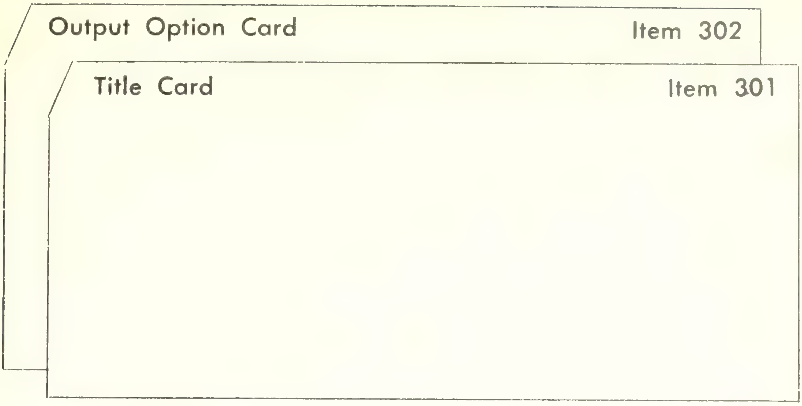


Figure 1. — Order of the job control cards in the job control deck.

TITLE CARD — ITEM 301

Columns	*Contain —*		*Explanation*
1-72	AAA . . . A	=	72 alphameric characters, giving a descriptive title for the job. The title will appear at the top of each page of printed output.

OUTPUT OPTION CARD — ITEM 302

Columns	*Contain —*		*Explanation*
1-6	OPTION	=	Card label.
7-8	bb		
9	1	=	Form and output tables of sampling unit sums over sets of sampling units.
	2	=	Form and output tables of sampling unit means over sets of sampling units.
	3	=	Form and output tables of sampling unit means and of their variances over sets of sampling units.
	4	=	Form and output tables of sampling unit means, their variances, and of covariances of table cells with table totals over sets of sampling units.
10-11	bb		
12-16	bbbbb	=	Output written on tape in binary mode. (See part VII-E for format.) This option is used for a normal processing run.
	DEBUG	=	Output is printed in binary coded decimal (BCD) mode. (See part VII-E for format.) This option may be used when debugging a new control deck.

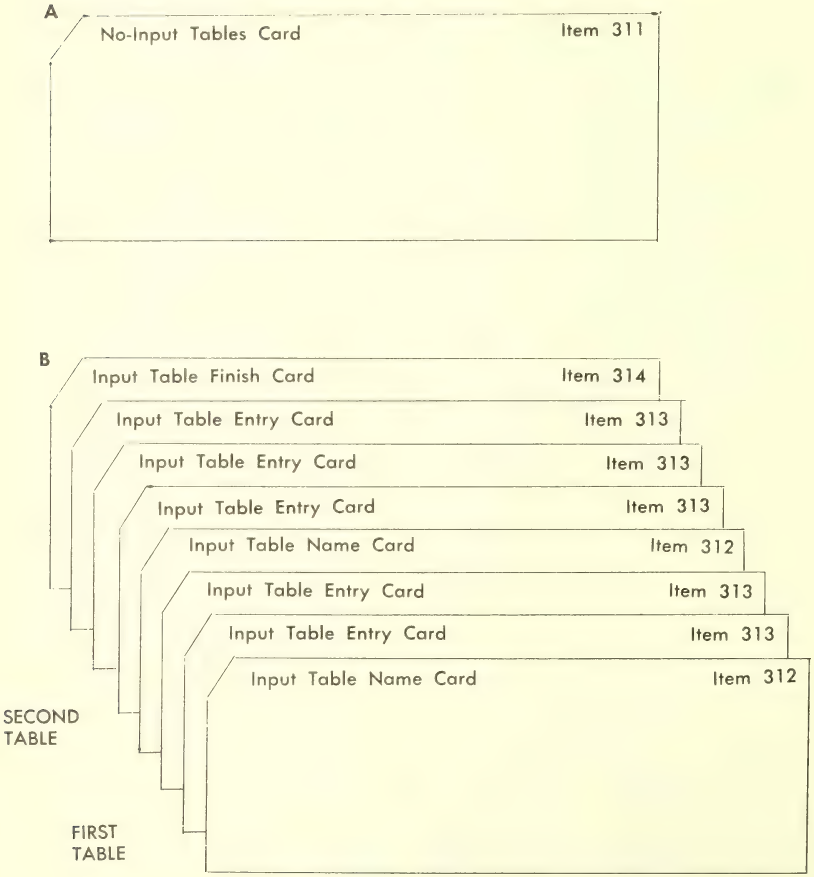
2. Input Table Cards (Sec. 310)

This section describes each type of card required in the control deck to provide the input tables used in the table indexing operations (see part V-D).

The no-input tables card (item 311) is to be used if the job does not require input tables for indexing. In this case no other input table cards need be used (fig. 2-A).

Any number of input tables may be put in the control deck, and

Figure 2. — Order of the input table cards in the job control deck; **A**, when the job requires no input tables; **B**, when the job requires two input tables, with two and three entries, respectively.



the tables may be in any order. However, all tables must be placed in the control deck as a group, and the last card of the group must be the input table finish card (item 314).

Two types of card are required for each input table, and the cards for each input table must appear as a set. The first card of each set is the input table name card (item 312) that gives a unique name to the table and controls the input of the table to the computer. The remaining cards of each set are repetitions of the input table entry card (item 313), in which a single input table entry appears. As many of these cards follow the input table name card as there are entries in the table (fig. 2-B).

The card following the last input table entry card (item 313) for a table must either be an input table name card (item 312) or an input table finish card (item 314).

NO-INPUT TABLES CARD — ITEM 311

Columns	*Contain —*	*Explanation*
1-15	NObINPUTbTABLES	= A control word signifying that there are no input tables in the control deck.

INPUT TABLE NAME CARD — ITEM 312

Columns	*Contain —*	*Explanation*
1-6	AAAAAA	= 6 alphameric characters, giving a unique name by which the input table is referenced to an operation. The user may assign any name he wishes but the name must be left-justified in the field.
7-15	bbb . . . b	= 9 blanks.
16-20	XXXXX	= 5 numeric characters, giving the number of entries in the table just named. The number must be right-justified in the field.
21	b	
22	1	= There is only one field in a table entry.
	2	= There are two fields in a table entry. This option is required for tables to be used with the LOOKUP and the RANGE operations.

INPUT TABLE ENTRY CARD — ITEM 313

Columns	*Contain —*	*Explanation*
1-4	XXXX	= 4 numeric characters, containing the value of the first field of a table entry. The number must be right-justified in the field.

5-8	XXXX	= 4 numeric characters, containing the value of the second field of a table entry, if any. The value must be right-justified in the field. A second field is required only if the table is to be used in the LOOKUP or the RANGE operations.

INPUT TABLE FINISH CARD — ITEM 314

Columns	*Contain —*	*Explanation*
1-6	FINISH	= A control word signifying the end of all input tables. This card must always follow the last table entry card of the last input table in the control deck. It should not be used if there are no input tables and the no input tables card (item 311) has been used.

3. Output Table Definition Cards (Sec. 320)

The control cards described in this section are used to define the output tables that are to be compiled from the input data for this job. The maximum number of tables that may be defined in one run is 40, and the maximum dimensions of any table are 50 rows by 50 columns, including the row and column totals that are automatically supplied by the program. The definition of output tables is subject to the additional restriction that the total number of cells in all tables defined is limited by the sampling option chosen and the available storage in the computer. This restriction is discussed further in part VII-C.

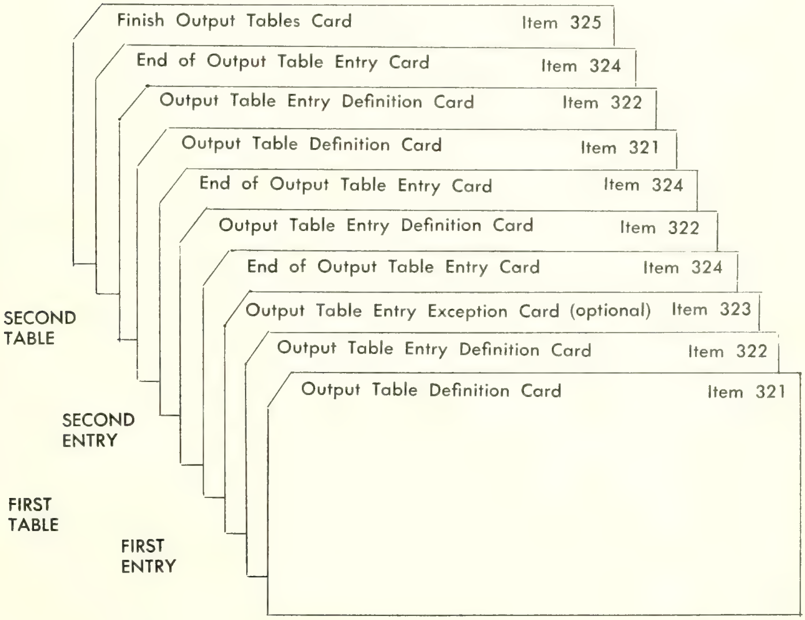
The definition of an output table gives the information required to produce the output table from the input data. The information is contained in a group of cards for each output table defined. The groups may be placed in the control deck in the order that the tables are to appear in the final output; but within the group for a given table, the order of the cards must be exactly as described below (fig. 3).

The first card in a group of cards defining an output table is the output table definition card (item 321). In this card the user assigns the table a unique name, gives its dimensions, and specifies the number of entries in the table per sampling unit.

Next in the group comes a set of cards (described below) in which the first table entry is completely defined. There must be as many of these sets as there are entries specified on the first card.

In the set of cards defining a table entry, the first card is the output table entry definition card (item 322). In this card the user gives the identification number of the input data field to be used as the table entry, and tells how to determine the row and the column of the table in which the entry is to be summed (part V-D). The last card in the set is the end of output table entry card (item 324), which simply signals the end of the set. Between these two cards may appear as many output table entry exception cards (item 323) as necessary to give the conditions under which the normal entry will not be made. Only one condition can be given on a card. The use of these cards is subject to the additional

Figure 3. — Order of the output table definition cards in the job control deck. This setup calls for two output tables, with two and one entries, respectively. The first entry of the first output table carries one condition for "excepting" the entry.


Finish Output Tables Card Item 325
End of Output Table Entry Card Item 324
Output Table Entry Definition Card Item 322
Output Table Definition Card Item 321
End of Output Table Entry Card Item 324
Output Table Entry Definition Card Item 322
End of Output Table Entry Card Item 324
Output Table Entry Exception Card (optional) Item 323
Output Table Entry Definition Card Item 322
Output Table Definition Card Item 321
SECOND TABLE
SECOND ENTRY
FIRST TABLE
FIRST ENTRY

restriction that there may not be more than 150 of them in the control deck for all entries in all tables.

Finally, the end of all output table definitions is signaled by the finish output tables card (item 325) that must always be present in the control deck (fig. 3).

OUTPUT TABLE DEFINITION CARD — ITEM 321

Columns	*Contain —*		*Explanation*
1-12	DEFINEbTABLE	=	Card label.
13	b		
14-19	AAAAAA	=	6 alphameric characters, giving a unique name by which the output table may be referenced. The user may assign any name he wishes, but the name must be left-justified in the field.
20-23	bbbb		
24-25	XX	=	2 numeric characters, giving the number of rows in the output table (exclusive of a row for column totals which is provided automatically). The number must be less than 50, and must be right-justified in the field.
26	A	=	The alphameric character, X, signifying "by," as in "rows by columns."
27-28	XX	=	2 numeric characters, giving the number of columns in the output table (exclusive of a column for row totals which is provided automatically). The number must be less than 50, and must be right-justified in the field.
29-32	bbbb		
33	X	=	1 numeric character, giving the total number of entries to be made in the table from each sampling unit processed. The number cannot exceed four.

OUTPUT TABLE ENTRY DEFINITION CARD — ITEM 322

Columns	*Contain —*		*Explanation*
1-6	AAAAAA	=	6 alphameric characters, giving the name of the output table in which the entry will be made. The name must be left-justified in the field, and must appear exactly as given in columns 14-19 of the output table definition card (item 321).
7-11	bbbbb		
12-17	LISTbb	=	Define the row index of the table entry as

the position number, in a list of all possible values, of the value in the data field identified in columns 19-21 of this card.

RANGEb = Define the row index of the table entry as the position number, in a list of all appropriate ranges, of the range that contains the value of the data field identified in columns 19-21 of this card.

LOOKUP = Define the row index of the table entry as the value in a list that is paired with the value in the data field identified in columns 19-21 of this card.

EQUATE = Define the row index of the table entry as the value in the data field identified in columns 19-21 of this card.

CONSTb = Define the row index of the table entry as the constant contained in columns 19-21 of this card.

18 b

19-21 XXX = 3 numeric characters, giving the value required in the operation named in columns 12-17 of this card. The value must be right-justified in the field. If the named operation is LIST, RANGE, LOOKUP, or EQUATE; the value will be the identification number of the required data field. If named operation is CONST, the value will be the value of the required constant.

22 b

23-28 AAAAAA = 6 alphameric characters, giving the name of the input table containing the list required in the operation named in columns 12-17 of this card. The name must be left-justified in the field, and must appear exactly as given in columns 1-6 of an input table name card (item 311).

29 b

30-35 LISTbb = Define the column index of the table entry as the position number, in a list of all possible values, of the value in the data field identified in columns 37-39 of this card.

RANGEb = Define the column index of the table entry as the position number, in a list of all appropriate ranges, of the range which contains the value in the data field identified in columns 37-39 of this card.

LOOKUP = Define the column index of the table entry as the value in a list that is paired with the value in the data field identified in columns 37-39 of this card.

	EQUATE	= Define the column index of the table entry as the value in the data field identified in columns 37-39 of this card.
	CONSTb	= Define the column index of the table entry as the constant contained in columns 37-39 of this card.
36	b	
37-39	XXX	= 3 numeric characters, giving the value required in the operation named in columns 30-35 of this card. The value must be right-justified in the field. If the named operation is LIST, RANGE, LOOKUP, or EQUATE; the value will be the identification number of the required data field. If the named operation is CONST, the value will be the required constant.
40	b	
41-46	AAAAAA	= 6 alphameric characters, giving the name of the input table which contains the list required in the operation named in columns 30-35 of this card. The name must be left-justified in the field, and must appear exactly as given in columns 1-6 of an input table name card (item 311).
47	b	
48-50	XXX	= 3 numeric characters, giving the identification number of the data field to be entered in the output table. The number must be right-justified in the field.

OUTPUT TABLE ENTRY EXCEPTION CARD (OPTIONAL) — ITEM 323

Columns	*Contain —*	*Explanation*
1-2	IF	= Card label.
3	b	
4-6	XXX	= 3 numeric characters, giving the identification number of the data field required in the exception operation. The number must be right-justified in the field.
7	b	
8-11	E.bb	= This entry is not made if the value in the data field identified in columns 4-6 is equal to the value of the constant in columns 13-17 of this card.
	L.E.	= This entry is not made if the value in the data field identified in columns 4-6 is less than or equal to the value of the constant in columns 13-17 of this card.

	G.E.	= This entry is not made if the value in the data field identified in columns 4-6 is greater than or equal to the value of the constant in columns 13-17 of this card.
	N.E.	= This entry is not made if the value in the data field identified in columns 4-6 is not equal to the value of the constant in columns 13-17 of this card.
12	b	
13-17	XXXXX	= 5 numeric characters, giving the value of the constant required in the exception operation.
18	b	
19-35	NObENTRYbINb-TABLE	= Card label.
36	b	
37-42	AAAAAA	= 6 alphameric characters, giving the name of the output table to which the entry and the exception apply. The name must be left-justified in the field, and must appear exactly as given in columns 14-19 of the output table definition card (item 321).

END OF OUTPUT TABLE ENTRY CARD — ITEM 324

Columns	*Contain —*	*Explanation*
1-3	END	= A control word signifying the end of a set of output table entry and exception cards. This card must follow every set of these cards and must be present even if there are no exception cards.

FINISH OUTPUT TABLES CARD — ITEM 325

Columns	*Contain —*	*Explanation*
1-6	FINISH	= A control word signifying the end of all output table definition cards. It must always follow the last end-of-output table entry card in control deck.

4. Input Record Description Cards (Sec. 330)

This group of cards contains a description of the physical configuration of the input data and of the kind of information contained in the data fields of each record. The individual cards are described below in the order that they must appear in the job control deck (fig. 4).

The first four types of control cards are used to describe the physical form of the input data. The input record control card (item 331) must always be present. It contains the number of data fields in each record, the mode in which the records are written, and the total number of records to be processed. The input record format card (item 332) is optional; it is used only if the input records are written in the binary coded decimal (BCD) mode. It contains a FORTRAN format specification which describes each input data field. The format continuation card (item 333) is also optional, being used only if the entire format specification cannot be punched in item 332.

Although the input data fields can be described by any appropriate format specification, special note should be made of the fact that values of data fields to be entered into output tables must be expressed at floating-point numbers, and values of data fields to be used in setting row and column indexes must be expressed as fixed-point numbers before the output tables can be made. If possible, therefore, data-field values should be expressed properly in the input file (whether written in binary or BCD). Otherwise, they will have to be converted to the proper expression in the CALCUL subroutine (part VII-B).

The input record identification fields card (item 334) must always be present. It is used to record the data fields that uniquely identify the data set, the sampling unit, and the subunit, if any, to which each record in the input data belongs. (See part V-C). A change in the value of any one of the data-set identification fields signals the end of a data set and causes the execution of the final computations and output of the summary tables for the data set. The data set identification will also appear in the output file preceding the output tables for the data set. A change in the value of any one of the sampling-unit identification fields signals the end of the sampling unit input records and causes the sampling-unit facsimile output tables to be summed into the data set output tables.

The remaining three types of control cards are used to classify the data fields of input records according to the way that the information they contain was observed (see part V-C). The input

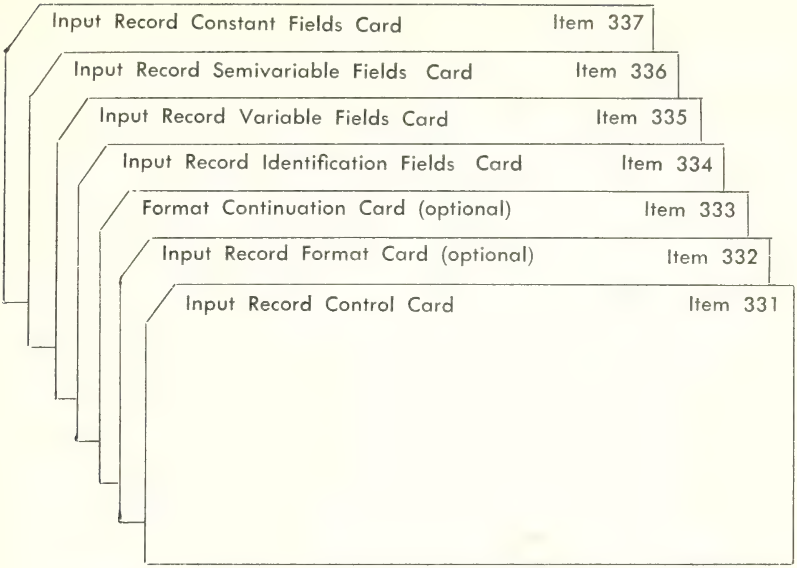

Input Record Constant Fields Card
Item 337
Input Record Semivariable Fields Card
Item 336
Input Record Variable Fields Card
Item 335
Input Record Identification Fields Card
Item 334
Format Continuation Card (optional)
Item 333
Input Record Format Card (optional)
Item 332
Input Record Control Card
Item 331

Figure 4. — Order of the input record description cards in the job control deck. The optional items are not needed when the data input tape file is written in the binary mode.

record variable fields card (item 335) is used to record the identification numbers of data fields that contain attributes observed on subdivision of subunits. The input record semivariable fields card (item 336) is used to record the identification numbers of data fields that contain attributes observed on subunits of sampling units. The input record constant fields card (item 337) is used to record the identification numbers of data fields that contain attributes observed on a sampling unit as a whole.

Every data field (input or otherwise) that is recorded in any other control card of the control deck or is used in the CALCUL subroutine must be identified on one of the above three field cards. Other data fields in the input record may also be identified in these cards, but this is optional. If a field is not identified in one of these cards, it will be automatically deleted from every input record.

INPUT RECORD CONTROL CARD — ITEM 331

Columns	*Contain —*	*Explanation*
1-12	INPUTbRECORD	= Card label.
13	b	
14-16	XXX	= 3 numeric characters, giving the total number of data fields in each input record. The number must be right-justified in the field. The maximum number is 132.
17	b	
18	1	= The input records are in binary mode.
	2	= The input records are in binary coded decimal (BCD) mode.
19	b	
20-25	XXXXXX	= 6 numeric characters, giving the total number of input records to be processed. This is the sum of the numbers of input records in each data set to be processed. The number must be right-justified in the field.

INPUT RECORD FORMAT CARD (OPTIONAL)

ITEM 332

Columns	*Contain —*	*Explanation*
1	0	= There is no format continuation card.
	1	= The format specification is continued on the next card (item 333).
2	b	
3	(	= Left parenthesis.
4-80	AAA . . . A	= Up to 77 alphameric characters, ending with a right parenthesis, and containing a FORTRAN format specification that describes the format of the input records if they are in the BCD mode. Data fields to be used in indexing operations must have an I (fixed-point) specification; those to be used as table entries must have E or F (floating-point) specifications.

FORMAT CONTINUATION CARD (OPTIONAL)

ITEM 333

Columns	*Contain —*	*Explanation*
1-72	AAA . . . A	= A continuation of the FORTRAN format specification described for the previous card (item 332).

INPUT RECORD IDENTIFICATION FIELDS CARD ITEM 334

Columns	*Contain —*	*Explanation*
1-11	DATAbSETbID	= Card label.
12	b	
13-15	XXX	= 3 numeric characters, giving the identification number of a data field in an input record in which the data set (sample stratum) is identified. The number must be right-justified in the field. Up to 5 data set identification fields may be identified in the following columns, and the identification numbers may be listed in any order.
16-27	XXX . . . X	= Repetitions of columns 13-15 format, giving the identification numbers of the remaining data fields by which the data set is identified.
28	b	
29-41	SAMPLINGb UNIT	= Card label.
42	b	
43-45	XXX	= 3 numeric characters, giving the identification number of a data field in an input record in which the sampling unit is identified. The number must be right-justified in the field. Up to five sampling-unit identification fields may be identified in the following columns, and the identification numbers may be listed in any order.
46-57	XXX . . . X	= Repetitions of columns 43-45 format, giving the identification numbers of the remaining data fields by which the sampling unit is identified.
58	b	
59-66	SUBbUNIT	= Card label.
67	b	
68-70	XXX	= 3 numeric characters, giving the identification number of the data field in an input record in which a subunit, if any, of a sampling unit is identified. The number must be right-justified in the field.

INPUT RECORD VARIABLE FIELDS CARD — ITEM 335

Columns	*Contain —*	*Explanation*
1-8	VARIABLE	= Card label.

9-11	XXX	= 3 numeric characters, giving the identification number of a data field in an input record in which the values vary from one record to another within the set of records for a sampling unit. The following columns may be used to identify up to 24 variable data fields for use in processing, and the identification numbers may be listed in any order.
12-80	XXX . . . X	= Repetitions of columns 9-11 format, giving the identification numbers of the remaining data fields that contain variable values.

INPUT RECORD SEMIVARIABLE FIELDS CARD
ITEM 336

Columns	*Contain —*	*Explanation*
1-8	SEMIbVAR	= Card label.
9-11	XXX	= 3 numeric characters, giving the identification number of a data field in an input record in which the values vary only from one set of subunit records to another; and are constant within the sets of subunit records. The number must be right-justified in the field. The following columns may be used to identify up to 24 semivariable data fields for use in processing. The identification numbers may be listed in any order.
12-80	XXX . . . X	= Repetitions of the columns 9-11 format, giving the identification numbers of the remaining data fields that contain semivariable values.

INPUT RECORD CONSTANT FIELDS CARD — ITEM 337

Columns	*Contain —*	*Explanation*
1-8	CONSTANT	= Card label.
9-11	XXX	= 3 numeric characters, giving the identification number of a data field in an input record in which the values are constant within the set of records for a sampling unit. The number must be right-justified in the field. The following columns may be used to identify up to 24 constant data fields for use in processing. The identification numbers may be listed in any order.
12-80	XXX . . . X	= Repetitions of the columns 9-11 format, giving the identification numbers of the remaining data fields that contain constant values.

5. End of Control Deck Card — Item 340

Columns	*Contain —*	*Explanation*
1-19	ENDbOFbCONTROLbDECK	= A control word signifying the last card in the control deck.

VI-C. OPERATING INSTRUCTIONS

This chapter gives information necessary to set up and process sample summarization jobs with program TABLE. It is, in part, a resume of information given elsewhere.

1. Program Restrictions

The standard version of the program carries restrictions on the overall size and on certain dimensions of a problem that can be handled in a single-processing run. They are:

1. The number of data fields in each input record must be no greater than 132.
2. The number of variable data fields must be no greater than 24.
3. The number of semivariable data fields must be no greater than 24.
4. The number of constant data fields must be no greater than 24.
5. The number of data fields used for data set identification must be no greater than five.
6. The number of data fields used for sampling unit identifica- must be no greater than five.
7. The subunit identification, if any, must be contained in a single-data field.
8. The total number of cells in all input and output tables must be no greater than 10,000.
9. The number of input tables must be no greater than 80.
10. The number of output tables must be no greater than 40.
11. The number of rows in each output table must be no greater than 50.

12. The number of columns in each output table must be no greater than 50.
13. The number of output table entries in each output table must be no greater than four.
14. The total number of output table entry exceptions for all output tables must be no greater than 150.

These restrictions result primarily from the way in which the available storage capacity of the computer has been allocated to various uses in the standard version of the program. However, the program has been constructed so that the more important of these allocations can readily be changed if a problem of substantially different relative dimensions is encountered. The modification of dimensioned space is described in part VII of this series.

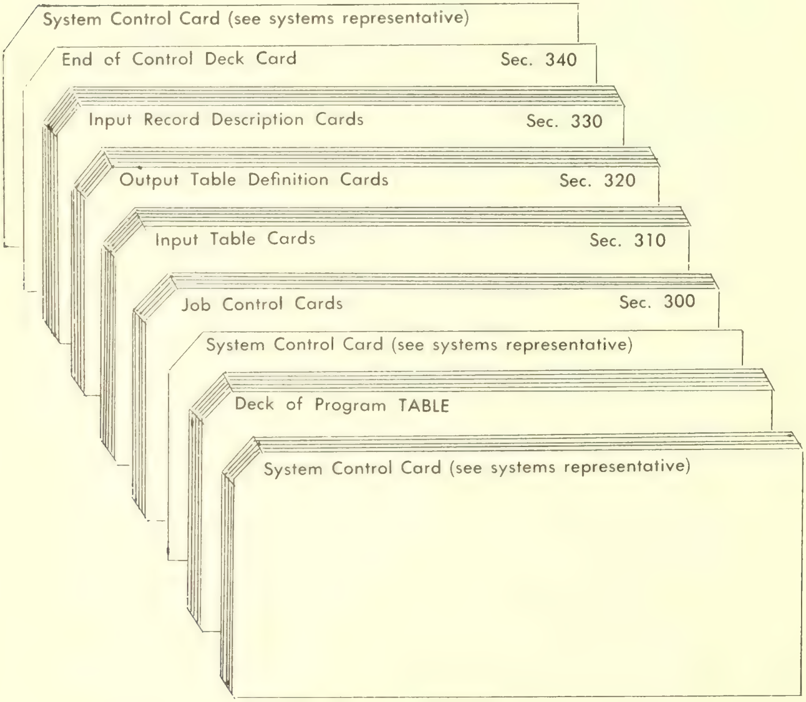

System Control Card (see systems representative)
End of Control Deck Card
Sec. 340
Input Record Description Cards
Sec. 330
Output Table Definition Cards
Sec. 320
Input Table Cards
Sec. 310
Job Control Cards
Sec. 300
System Control Card (see systems representative)
Deck of Program TABLE
System Control Card (see systems representative)

Figure 5.—The job control deck setup, illustrating the kinds of cards that are necessary and the order in which they must be arranged.

2. Job Control Deck Setup

The job control deck consists of all the punched cards through which processing specifications, necessary constants, and other data (exclusive of the data to be processed) are entered into the computer. These cards, and the logical groups into which they fall, have been described in the previous chapter. The assembly of the groups of control cards to form the job control deck, as well as the placement of that deck in the monitor input deck, are shown in figure 5.

It should be noted that the monitor input deck consists of the program deck, followed by the control deck, with system control cards interspersed. The latter cannot be described in detail here because they will vary from one computer system to another. For more information about them, see the systems representative at the computer center where the processing will be done.

3. Input Data Setup

Data input must be in the form of a single magnetic tape file of records. Multiple record files for a job must either be gotten into a single file or be processed in multiple passes of the program. The file may be written either in binary or BCD mode.

Each record must have the same format and contain no more than 132 data fields. Values in data fields to be entered in output tables should be expressed as floating-point numbers, while those in data fields to be used in setting row and column table indexes should be expressed as fixed-point numbers.

The records must be sorted by sampling unit, and the sets of records for each sampling unit must be sorted by the data set (sample) to which they belong. Additional sorting is permitted but not required. It will depend on how the output is to be used (see program OUTPUT).

Normally, the input tape file will have been produced in the correct form by the processing of the original data through programs EDIT and SORT. (For information about the first see part II of this series, and for the second see your computer systems representative.) However, if the input tape file is not produced in the correct form, use appropriate IBM 1401 programs or see your systems representative.

4. Tape Assignments

In the standard version of program TABLE the FORTRAN logical tape assignments are as follows:

Unit	*Use*
5	Monitor input for program deck and job control deck.
6	Monitor print for job summary and debug output.
15	Sorted input tape file in binary or BCD.
19	Output of sample summary tables in binary only.

These tape assignments can be changed to fit local conditions by loading appropriate file routines with the program. See your systems representative or the section entitled FORTRAN files in the IBM IBJOB processor manual, file number 7090-27.

5. Use of Sense Switches and Sense Lights

No sense switches are used in program TABLE. All sense switches will be set at normal monitor settings.

No sense lights are used.

6. Use of Program Halts

There are no halts in program TABLE.

7. Use of the Overlay Feature

The standard version of program TABLE is constructed so that the overlay feature can be used when sufficient storage is not available for program and data. The configuration is as follows:

Link	*Contains Subprograms*
0	MAINT
1	CONTRL
2	TABLE, CALCUL, STONO, GETNO, VARIAN

8. Messages Printed During Execution

The messages listed below are those produced by the program during execution. Each message, with its consequences, is described; and the appropriate action, if any, is indicated.

FIRST INPUT CARD IS INCORRECT

Message 1. This message means either that the output option card (item 302) is missing from the control deck or that the card label in columns 1-6 is punched incorrectly. Correct the error and start processing from the beginning.

TABLE AAAAAA CONSISTING OF XXXXX CARDS HAS BEEN READ CORRECTLY

Message 2. This message prints each time an input table has been read successfully. AAAAAA is the table name punched in columns 1-6 of the input table name card (item 312). XXXXX is the number of entries read for the named table, taken from columns 16-20 of the input table name card (item 312).

INPUT TABLE AAAAAA EXCEEDED MACHINE CAPACITY

Message 3. This message is printed if the total number of entries in all input tables (sec. 310) exceeds the computer storage available (see appendix B). AAAAAA is the name of the input table being read when available storage was exceeded, as punched in columns 1-6 of an input table name card (item 312). The number or size of input tables must be reduced, or the available storage must be increased before processing can be started again from the beginning.

TABLE DEFINITION CARDS ARE OUT OF ORDER. TABLE AAAAAA

Message 4. This message is printed if columns 1-6 of the output table definition card (item 321) are mispunched, or if the cards which define the output tables are not in the proper sequence (see sec. 320). AAAAAA is the first six columns of the offending card. Correct the error and start again from the beginning.

MORE THAN 4 ENTRIES IN TABLE AAAAAA

Message 5. This message is printed if column 33 of an output table definition card (item 321) is punched with a zero or a number greater than four. AAAAAA is the name of the table, punched in columns 14-19 of the same card. Correct the error and start processing from the beginning.

TABLE AAAAAA HAS EXCEEDED AVAILABLE STORAGE

Message 6. This message is printed if the total number of entries in all input tables (see sec. 310), plus the space required for all output tables (see sec. 320), has exceeded the total storage available (see part VII C). AAAAAA is the name of the output table being defined when available storage was exceeded. It corresponds to columns 14-19 of an output table definition card (item 321). The number or size of input and output tables must be reduced, or available storage must be increased before processing can be started again from the beginning.

AN OPERATION HAS BEEN MISSPELLED IT STARTS — AAAAAA

Message 7. This message is printed if columns 12-17 or 30-35 of an output table entry definition card (item 322) are not punched with a valid operation name. AAAAAA is the operation name punched in the offending card. Correct the error and start processing from the beginning.

THE NAME AAAAAA IS NOT THE NAME OF AN INPUT TABLE

Message 8. This message is printed if the name punched in columns 23-28 or 41-46 of an output table entry definition card (item 322) does not correspond to the name of an input table as punched in columns 1-6 of an input table name card (item 312). AAAAAA is the input table name punched in the offending card. Correct the error and start processing from the beginning.

THE TABLE NAME AAAAAA GIVEN ON AN EXCEPTION CARD, DOES NOT AGREE WITH TABLE DEFINITION CARD

Message 9. This message is printed if the name punched in columns 37-42 of the output table entry exception card (item 323) does not agree with the name punched in columns 14-19 of the output table definition card (item 321). AAAAAA is the name punched in columns 37-42 of the output table exception card. Correct the error and start processing from the beginning.

THE EXCEPTION DEFINED BY AAAAAA IS INCORRECT

Message 10. This message is printed if the relational operator punched in columns 8-11 of the output table exception card (item 323) is not one of those listed. Correct the error and start processing from the beginning.

INPUT CONTROL CARD IS NOT CORRECT

Message 11. This message is printed if columns 1-6 of the input record control card (item 331) are punched incorrectly or if a card is out of order. Correct the error and start processing from the beginning.

FIELD IDENTIFICATION CONTROL CARD IS INCORRECT

Message 12. This message is printed if columns 1-6 of the input record identification fields card (item 334) are punched incorrectly or a card is out of order. Correct the error and start processing from the beginning.

CARD ENUMERATING VARIABLE FIELDS IS INCORRECT. AAAAAA

Message 13. This message is printed if columns 1-6 of the input record variable field card (item 335) are punched incorrectly. AAAAAA are the characters punched in the first six columns of the card. Correct the error and start processing from the beginning.

CARD ENUMERATING SEMIVARIABLE FIELDS IS INCORRECT. AAAAAA

Message 14. This message is printed if columns 1-6 of the input record semivariable field card (item 336) are punched incorrectly. AAAAAA are the characters punched in the first six columns of the card. Correct the error and start processing from the beginning.

CARD ENUMERATING CONSTANT FIELDS IS INCORRECT. AAAAAA

Message 15. This message is printed if columns 1-6 of the input record constant field card (item 337) are punched incorrectly. AAAAAA are the characters punched in the first six columns of the card. Correct the error and start processing from the beginning.

SOME FIELD HAS BEEN DEFINED AT TWO OR MORE LEVELS

Message 16. This message is printed if the same field appears on two or more of the cards described in items 335 to 337. Correct the error and start processing from the beginning.

THE FIELD USED FOR AN ENTRY IN TABLE AAAAAA HAS NOT BEEN DEFINED

Message 17. This message is printed if the field to be used for a table entry (columns 48-50 of the output table entry definition card, item 322) has not been defined on one of the input record field cards (items 335 to 337). AAAAAA is the name punched in columns 14-19 of the output table definition card (item 321). Correct the error and start processing from the beginning.

FIELD USED FOR TABLE AAAAAA HAS NOT BEEN DEFINED OR THE ROW OR COLUMN INDEX IS ON A LOWER LEVEL THAN THE TABLE ENTRY

Message 18. This message is printed if the field to be used for a row or column index (columns 19-21 or columns 37-39 of the output table entry definition card (item 322) has not been defined on one of the input record field cards (items 335 to 337) or if the row or column field are defined on a lower level than the table entry field; that is, if the entry field is defined as a variable, the row and column fields can be defined at any level; if the entry field is defined as a semivariable, the row and column field cannot be defined at the variable level; if the entry field is defined as a constant, the row and column fields must be defined at the constant level. AAAAAA is the name of the table to which the entry or row or column field applies, that is, the name punched in columns 14-19 of the output table definition card (item 321). Correct the error and start processing from the beginning.

UNDEFINED DATA FIELD XXXXXX

Message 19. This message is printed if the argument NDAFL to subroutine GETNO or STONO has not been defined on one of the input record field identification cards (items 335 to 337). Correct the error and start processing from the beginning.

ALL DEFINITION AND IDENTIFICATION CARDS READ

Message 20. This message prints if all control cards have been read and no errors have been detected.

THE NUMBER OF INPUT RECORDS IS YYYYY IN EXCESS OF THE ZZZZZ ALLOWABLE IN SAMPLING UNIT NO. XXXXX XXXXX XXXXX XXXXX XXXXX

Message 21. This message prints when the number of input records for a sampling unit is greater than the value ZZZZZ of the variable LTRCD which dimensions the sampling unit storage array TREE. Processing is continued using the first ZZZZZ records read for the sampling unit. If, at the end of the run, the accumulated errors cannot be tolerated, increase the value of LTRCD (see part VII-C) and rerun the job.

THE ROW OR COLUMN INDEX CANNOT BE FOUND FOR OUTPUT TABLE AAAAAA, ENTRY NO. ZZZZZ, IN SAMPLING UNIT NO. XXXXX XXXXX XXXXX XXXXX XXXXX, RECORD NO. YYYYY.

Message 22. This message is printed when a correspondence cannot be found between a field in the input for the sampling unit and a table used in a LIST, LOOKUP, or RANGE operation. The entry in question is not made in the output table but processing continues. If the error cannot be tolerated, the input data field, the input table, or both must be corrected and the job must be rerun from the beginning.

THE ROW OR COLUMN INDEX IS TOO LARGE FOR OUTPUT TABLE AAAAAA, ENTRY NO. ZZZZZ, IN SAMPLING UNIT NO. XXXXX XXXXX XXXXX XXXXX XXXXX, RECORD NO. YYYYY

Message 23. This message is printed when the value of a row or column index exceeds the number of rows or columns punched in columns 24-25 or columns 27-28 of the output table definition card (item 321) for output table AAAAAA. The entry in question is not made in the output table but processing continues. If the error cannot be tolerated, it must be corrected and the job must be rerun from the beginning.

THE ROW OR COLUMN INDEX IS ZERO FOR OUTPUT TABLE AAAAAA, ENTRY NO. ZZZZZ, IN SAMPLING UNIT NO. XXXXX XXXXX XXXXX XXXXX X, RECORD NO. YYYYY

Message 24. This message is printed when a row or column index is set equal to zero. The entry in question is not made in the output table but processing continues. If the error cannot be tolerated, it must be corrected and the job must be rerun from the beginning.

YYYYY SAMPLE UNITS READ IN DATA SET XXXXX XXXXX XXXXX XXXXX XXXXX

Message 25. This message is printed at the end of each data set processed. The data set identification is taken from the data fields identified in columns 13-27 of the input record identification fields card (item 334). YYYYY is the number of sampling units in the data set that were actually processed.

XXXX DATA SETS HAVE BEEN PROCESSED

Message 26. This message is printed at the termination of the run. XXXX is the number of data sets actually processed.

```
THE NAMES OF      NUMBER OF       NUMBER OF
 THE TABLES          ROWS          COLUMNS
   AAAAAA             XX              YY
     !                 !               !
     !                 !               !
     !                 !               !
```

Message 27. These are summaries which are printed at the end of processing and list all output tables produced. They are listed by the name (AAAAAA) given in columns 14-19 of the output table definition card (item 321), and the number of rows (XX) and number of columns (YY) (including totals) for each table is given.

■

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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM.

VII. INFORMATION FOR PROGRAMMERS SUBSYSTEM TABLE.

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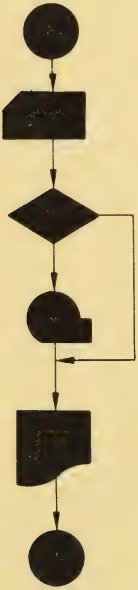

by
Robert C. Peters and
Robert W. Wilson Jr.

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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THE NORTHEASTERN FOREST-INVENTORY DATA-PROCESSING SYSTEM. VII. INFORMATION FOR PROGRAMMERS SUBSYSTEM TABLE.

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PREFACE

THIS paper is the seventh in a series of ten papers prepared to describe the forest-inventory data-processing system of the Northeastern Forest Experiment Station. This system was devised for using modern, large-scale, high-speed computers in processing forest-inventory data. The series will comprise the following papers:

I. Introduction.
II. Description of subsystem EDIT.
III. Operation of subsystem EDIT.
IV. Information for programmers — subsystem EDIT.
V. Description of subsystem TABLE.
VI. Operation of subsystem TABLE.
VII. Information for programmers—subsystem TABLE.
VIII. Description of subsystem OUTPUT.
IX. Operation of subsystem OUTPUT.
X. Information for programmers — subsystem OUTPUT.

VII-A. INTRODUCTION

ONE of the major projects of the U. S. Forest Service is a nationwide forest survey, which is designed to obtain useful and timely information about the timber resources of the United States. In the course of the surveys, which are made mainly on a state-by-state basis, great masses of detailed data are collected about timber volumes, growth, timber cut, and other characteristics of the timber resource.

In recent years the volume of information obtained from forest-survey field plots has increased greatly. The task of compiling and analyzing this mass of data with mechanical computing machines was both cumbersome and time-consuming.

A solution to this problem was seen in the development of the high-speed electronic computers. The Northeastern Forest Experiment Station, which was responsible for conducting the forest survey of the heavily forested Northeastern States, investigated the possibilities and devised the Northeastern Forest-Inventory Data-Processing System.

This paper presents information for programmers about part of the system, subsystem TABLE. Program TABLE is designed specifically to reduce large volumes of sample data to tables of statistics for the samples. The output of these sample summaries, in turn, is designed for use with program OUTPUT (see part VIII of this series) to produce equivalent tables of statistics for the sampled populations.

A general description of the program and detailed instructions for its use in solving data-processing problems are given in parts V and VI of this series. In the following chapters will be found selected programming information that will be useful if the programs must be modified for any reason. The program writeups and information on the program source decks may be obtained from the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.

This program is written in the standard IBM FORTRAN IV language, and is operative at the Yale University Computer Center on an IBM 7094/7040 direct coupled system under the IBSYS DCS operating system with IBJOB processor.[1] It will operate with little or no modification on other comparable systems. The main requirements for a machine on which to operate the standard version of the program are a 32K word core, a minimum of 36 bits per word, binary arithmetic capability, and 5 tape drives or equivalent input/output devices.

VII-B. USE OF CALCULATE SUBROUTINE

The normal version of program TABLE provides a dummy calculate routine named CALCUL. If the user wishes, he may program this routine either to generate new data fields in the input matrix or to change existing data fields. The subroutine which he must substitute for the dummy has the following calling sequence and DIMENSION statement:

```
  SUBROUTINE CALCUL(TREE, ITREE, PLOT, IPLOT, POINT,
1 IPOINT, NCORR, LTRCD, LTRVR, LPLVR, LPTCRD, LPTVR,
2 NZAPS, NCARD, KPOINT)
```

```
  DIMENSION TREE(LTRCD, LTRVR), ITREE(LTRCD, LTRVR),
1 PLOT(LPLVR), IPLOT(LPLVR), POINT(LPTCRD, LPTVR),
2 IPOINT(LPTCRD, LPTVR), NCORR(NZAPS)
```

Two additional subroutines are provided to retrieve (GETNO) and to store (STONO) data fields from the input matrix. All the user need do is supply the appropriate information in the calling sequence of these routines to carry out either operation. These routines are called in the following manner:

```
  CALL GETNO (NDAFL, NFXFL, ANS, IANS, NXE, TREE,
1 ITREE, PLOT, IPLOT, POINT, IPOINT, NCORR, LTRCD,
2 LTRVR, LPLVR, LPTCRD, LPTVR, NZAPS, NCARD, KPOINT)
  CALL STONO (NDAFL, NFXFL, ANS, IANS, NXF, TREE,
1 ITREE, PLOT, IPLOT, POINT, IPOINT, NCORR, LTRCD,
2 LTRVR, LPLVR)
```

The user supplies values for the variables NDAFL, NFXFL, ANS, IANS, and NXF. They mean the following:

---

[1] Mention of a particular product should not be construed as an endorsement by the Forest Service or the U. S. Department of Agriculture.

VARIABLE	*STONO*	*GETNO*
NDAFL	Number of data field to be stored in matrix.	Number of data field to be retrieved from matrix.
NFXFL	Mode of data field to be stored: 1 = fixed; 2 = floated	Mode of data field to be retrieved: 1 = fixed; 2 = floated
ANS	If mode is 2, value of data field to be stored.	If mode is 2, value of data field retrieved.
IANS	If mode is 1, value of data field to be stored.	If mode is 1, value of data field retrieved.
NXF	Index to determine position of data field in matrix. If data field to be stored has been defined on the CONSTANT (item 337), level NXF = 0. If data field to be stored has been defined on SEMI VARIABLE LEVEL (item 336), NXF runs from 1 to KPOINT. If data field to be stored has been defined on VARIABLE level (item 335), NXF runs from 1 to NCARD.	

For example, a routine used to test GETNO and STONO is the following:

```
  SUBROUTINE CALCUL (TREE, ITREE, . . .
  DIMENSION TREE(LTRCD, LTRVR), . . .
  DO 1 I = 1, NCARD
  NXF = I
  CALL GETNO (10, 2, ANS, IANS, NXF . . .
  STOAN = ANS * 10.
  CALL STONO (10, 2, STOAN, IANS, NXF . . .
1 CONTINUE
  RETURN
  END
```

This routine takes data field number 10, which is a floating-point number and has been defined on the VARIABLE card (part VI, item 335), and multiplies it by 10.0 and then stores the product of data field 10 and the constant 10.0 back into data field 10. This is done NCARD times thus performing the operation on data field 10 in each of the records making up the sampling unit.

VII-C. MODIFICATION OF DIMENSIONED SPACE

The standard version of program TABLE carries restrictions on both the dimensions and the overall size of problem that can be handled in a single-processing run. These restrictions are a result of the manner in which dimensioned space has been allocated (table 1) and the total space available in a given operating system. The program has been written so that all modifications of

Table 1. — Summary of dimensioned space restrictions, and associated program variables and arrays

Item	Restrictions	Variable	Arrays
Maximum number of input records per sampling unit	160	LTRCD	TREE, ITREE
Maximum number of subunits per sampling unit	10	LPTCRD	POINT, IPOINT
Maximum number of data fields per record	132	LIVR*	R
Maximum number of variable data fields	24 + 1	LTRVR*	TREE, ITREE
Maximum number of semi-variable data fields	24 + 1	LPTVR*	POINT, IPOINT, LPOINT
Maximum number of constant data fields	24 + 1	LPLVR*	PLOT, IPLOT, LPLOT
Maximum number of cells in all input and output tables	10,000	NDIMEN	AIMP, IMP
Maximum number of input tables	80	LINTB	NTAB
Maximum number of output tables	40	LDETB	INF, NADD, TNAME
Maximum number of output table exceptions	150	LNEX	EXCEP, NEXCEP

* NZAPS must always be equal either to LIVR or to the sum of the values of LTRVR, LPTVR, and LPLVR, whichever is larger. In the DIMENSION statement, the dimension of NCORR must always be equal to NZAPS, also.

dimensioned space can be made in the subprogram called MAINT. No other parts of the program need be touched for this purpose. The use of dimensioned space and the means of changing dimensions are discussed in detail below.

Number of Input Records per Sampling Unit

In the standard version of program TABLE, up to 160 input records may be processed per sampling unit. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LTRCD must be set equal to the desired maximum value.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the first dimension of the arrays TREE and ITREE equals the new value of LTRCD.

Number of Subunits per Sampling Unit

In the standard version of program TABLE, up to 10 subunits may be processed per sampling unit. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LPTCRD must be set equal to the desired maximum value.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the first dimension of the arrays POINT and IPOINT equals the value of LPTCRD.

Number of Data Fields per Record

In the standard version of program TABLE, up to 132 data fields may be contained in a record. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LIVR must be set equal to the desired maximum value.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of the array R equals the new value of LIVR.

Number of Variable Data Fields per Record

In the standard version of program TABLE, up to 24 data fields may be specified as containing variable values (see item 335). To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LTRVR must be set equal to the desired maximum value plus one.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of LTREE and the second dimension of arrays TREE and ITREE equals the new value of LTRVR.
3. In the subprogram called MAINT, the variable named NZAPS must be set equal either to LIVR or to the sum of the values of the constants LTRVR, LPTVR, and LPLVR, whichever is greater.
4. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of array NCORR equals the new value of NZAPS.
5. In the control deck, if the desired maximum value is greater than 24, the input record variable fields card (item 335) must be followed by additional cards of the following format:

Columns	*Contain —*	*Explanation*
1-3	XXX	= 3 numeric characters, giving the identification number of the 25th data field that contains variable values, as described for item 335.
4-78	XXX . . . X	= Repetitions of columns 1-3 format, giving the identification numbers of the remaining data fields that contain variable values.

Number of Semivariable Data Fields per Record

In the standard version of program TABLE, up to 24 data fields may be specified as containing semivariable values (see item 336). To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LPTVR must be set equal to the desired maximum value plus one.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the second dimension of arrays POINT and IPOINT equals the new value of LPTVR.
3. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of array LPOINT equal the new value of LPTVR.
4. In the subprogram called MAINT, the variable named NZAPS must be set equal either to LIVR or to the sum of the values of the constants LTRVR, LPTVR, and LPLVR, whichever is greater.
5. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of the array NCORR equals the new value of NZAPS.
6. In the control deck, if the desired maximum value is greater than 24, the input record semivariable fields card (item 336) must be followed by additional cards of the following format:

Columns	*Contain —*	*Explanation*
1-3	XXX	= 3 numeric characters, giving the identification number of the 25th data field that contains semi-variable values, as described for item 336.
4-78	XXX . . . X	= Repetitions of the columns 1-3 format, giving the identification number of the remaining data fields which contain semivariable values.

Number of Constant Data Fields per Record

In the standard version of program TABLE, up to 24 data fields may be specified as containing constant value (see item 337). To change this maximum, the following steps (and only these) may be taken:

1. In the subprogram called MAINT, the variable named LPLVR must be set equal to the desired maximum value plus one.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of the arrays PLOT, IPLOT, and LPLOT equal the new value of LPLVR.
3. In the subprogram called MAINT, the variable named NZAPS must be set equal either to LIVR or to the sum of the values of the constants LTRVR, LPTVR, and LPLVR, whichever is greater.
4. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of the array NCORR equals the new value of NZAPS.
5. In the control deck, if the desired maximum value is greater than 24, the input record constant fields card (item 337) must be followed by additional cards of the following format:

Columns	*Contain —*		*Explanation*
1-3	XXX	=	3 numeric characters, giving the identification number of the 25th data field that contains constant values, as described for item 337.
4-78	XXX . . . X	=	Repetitions of the columns 1-3 format, giving the identification numbers of the remaining data fields that contain constant values.

Number of Cells in All Input and Output Tables

In the standard version of program TABLE, up to 10,000 locations are available for storing all input and output tables. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named NDIMEN must be set equal to the desired maximum value.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of the arrays AIMP and IMP equals the new value of NDIMEN.

If the space required for the input and output tables specified in a given control deck exceeds the dimensioned space, message 3 or message 6 will be printed during the reading of the control deck, and processing will halt. The space required can be computed as follows:

$$\left[\sum_{i=1}^{m}(e_i)\right] + K\left[\sum_{j=1}^{n}(r_j+1)\times(c_j+1)\right] +$$

$$\left[(r_{max}+1)\times(c_{max}+1)\right]$$

where

m = the total number of input tables.

e_i = the total number of entries in the ith input table.

K = a multiplier, the value of which depends upon the output option (item 302, column 9); as follows:

Option	*Value of K*
1 or 2	1
3	2
4	3

n = the total number of output tables.

r_j = the number of rows in the jth output table, as specified in columns 24-25 of item 321.

c_j = the number of columns in the jth output table, as specified in columns 27-28 of item 321.

r_{max} = the number of rows in the largest output table.

c_{max} = the number of columns in the largest output table.

Number of Input Tables

In the standard version of program TABLE, up to 80 input tables may appear in the control deck. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LINTB must be set equal to the desired maximum value.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the first dimension of the array NTAB equals the new value of LINTB.

Number of Output Tables

In the standard version of program TABLE, up to 40 output tables may be specified in the control deck. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LDETB must be set equal to the desired maximum value.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the first dimension of the arrays INF and NADD equals the new value of LDETB.
3. In the subprogram called MAINT, the DIMENSION statement must be changed so that the dimension of the array TNAME equals the new value of LDETB.

Number of Output Table Exceptions

In the standard version of program TABLE, up to 150 output table exceptions (item 323) can appear in the control deck. To change this maximum, the following steps (and only these) must be taken:

1. In the subprogram called MAINT, the variable named LNEX must be set equal to the desired maximum value.
2. In the subprogram called MAINT, the DIMENSION statement must be changed so that the first dimension of the arrays EXCEP and NEXCEP equals the new value of LNEX.

VII-D. PROGRAMMING FEATURES

The following items will be of interest to programmers who plan to modify the standard version of program TABLE for use on other computers or under other operating systems.

Tape Assignments

In the standard version of program TABLE the FORTRAN logical tape assignments are as follows:

Unit	*Use*
5	Monitor input for program deck and job control deck.
6	Monitor print for job summary and debug output.
15	Sorted input file in binary or BCD.
19	Output of sample summary tables in binary only.

These tape assignments can be changed to fit local conditions by loading appropriate file routines with the program. See your systems representative or the section entitled FORTRAN files in the IBM IBJOB processor manual, file number 7090-27.

Use of Sense Switches and Sense Lights

No sense switches are used in program TABLE. All sense switches will be set at normal monitor settings.

No sense lights are used.

Use of Program Halts

There are no halts in program TABLE.

Use of the Overlay Feature

The standard version of program TABLE is constructed so that the overlay feature can be used when sufficient storage is not available for program and data. The configuration is as follows:

Link	*Contains Subprograms*
0	MAINT
1	CONTRL
2	TABLE, CALCUL, STONO, GETNO, VARIAN

Bit Manipulation

Program TABLE uses 36-bit, fixed-point words for all input table entries. Certain types of tables (LOOKUP and RANGE operation) use several numbers packed in a single word. These numbers are packed and unpacked by the use of binary arithmetic. The program will not operate on a machine that uses either a larger or smaller number of bits in fixed-point operation unless the shift constants that are used to pack and unpack these words are changed to correspond with the word length.

Subprogram Names and Functions

CONTRL	Reads all cards in the control deck and sets up storage array for processing input data.
TABLE	Reads input data and forms tables defined in control deck for each sample unit and data set.
VARIAN	Computes variances and means for a data set and writes final table on tape 19. Called by subprogram TABLE.
CALCUL	User-written subprogram to compute attributes not present in a usable form on the input data. Called by subprogram TABLE.
STONO	Used to store calculated data field in the input matrix. Called from subprogram CALCUL.
GETNO	Used to retrieve data field from the input matrix. Called from subprogram CALCUL.

MAINT	Main calling program in which dimensions of all arrays are set. Calls subprograms CONTROL and TABLE.

Important Arrays and Variables

The following are the principal arrays and variables used in program TABLE:

Array	*Dimension*	*Description*
AIMP, IMP	NDIMEN	Floating- and fixed-point storage array for all input and output tables.
NTAB	LINTB x 4	Indexing information for all input tables; where LINTB is the number of input tables, and locations in the second dimension are used as follows: 1 = the alphameric name of the input tables. 2 = the beginning location of a table in IMP. 3 = the last location of a table in IMP. 4 = the number of entries in a table.
INF	LDETB x 35	Indexing information for all output tables; where LDETB is the number of output tables, and the locations in the second dimension are used as follows: 1 = The number of rows in an output table, plus 1. 2 = The number of columns in an output table, plus 1. 3 = The beginning location in IMP of a facsimile output table, less 1 plus the number of rows in the table. 4 = The beginning location in IMP of a final output table, less one plus the number of rows in the table. 5 = The beginning location in IMP of the sums of squares for a final output table, less one plus the number of rows in the table. 6 = The beginning location in IMP of the sums of cross-products, if any, less one plus the number of rows in the table. 7 = The number of entries to be made in an output table. 8 = The name of the input table, if any, to be used in defining the column index for the first entry in an output table. 9 = The name of the operation to be used in defining the column index for the first entry in an output table. 10 = The identification number of the data field or value of the constant to be used

Array	*Dimension*	*Description*
		in defining the column index for the first entry in an output table. 11-13 = Same as 8-10, except that the information relates to defining the row index of the first entry in an output table. 14 = The identification number of the data field to be used as the first entry in an output table. 15-21 = Same as 8-14, except that the information relates to the second entry to be made in an output table, if any. 22-28 = Same as 8-14, except that the information relates to the third entry to be made in an output table, if any. 29-35 = Same as 8-14, except that the information relates to the fourth entry to be made in an output table, if any.
EXCEP, NEXCEP	LNEX x 3	Storage array for read-in information about table entry exceptions, where LNEX is the number of exceptions in the job and the locations of the second dimension are used as follows: 1 = The identification number of the data field to which the exception applies. 2 = The value of the constant to be used in making the exception. 3 = The relational operator to be used in making the exception.
NADD	LDETB x 8	Indexing information for input table entry exceptions stored in EXCEP; where LDETB is the number of output tables, and the locations of the second dimension are used as follows: 1 = The index of the row in EXCEP where the first exception for the first entry in an output table is stored. 2 = The number of sequential exceptions applying to the first entry in an output table. 3-4 = Same as 1-2, except that the information applies to the second entry in an output table, if any. 5-6 = Same as 1-2, except that the information applies to the third entry in an output table, if any. 7-8 = Same as 1-2, except that the information applies to the fourth entry in an output table, if any.
NCORR	NZAPS	Storage array for the storage (machine) locations of the data fields of an input record, where NZAPS

Array	*Dimension*	*Description*
		is equal to or greater than the number of data fields in the record.
PLOT, IPLOT	LPLVR	Floating- and fixed-point storage array for data fields in the input records defined as constant fields (item 337).
TREE, ITREE	LTRCD x LTRVR	Floating- and fixed-point storage array for data fields in the input records defined as variable fields (item 335).
POINT, IPOINT	LPTCRD x LPTVR	Floating- and fixed-point storage array for data fields defined as semivariable fields (item 336).
R	LIVR	Storage array into which each individual input record is read from the input tape, where LIVR is the number of data fields in the record.
LPLOT	LPLVR	Storage array for the identification numbers of the input data fields defined as constant fields (item 337).
LPOINT	LPTVR	Storage array for the identification numbers of the data fields defined as semivariable fields (item 336).
LTREE	LTRVR	Storage array for the identification numbers of the data fields defined as variable fields (item 335).
IDPLOT	6	Storage array for the identification numbers of the input data fields defined as sampling-unit identification (item 334).
IDPT	1	Storage for the identification number of the data field defined as subunit identification, if any (item 334).
IDPI	6	Storage array for the identification numbers of the data fields defined as data-set identification (item 334).
IDPIO	6	Storage array for the identification data fields for the current data set.
IZDPIO, PIDPIO	6	Storage array for the identification data fields for the previous data set.
IDPLO	6	Storage array for the identification data fields of the current sampling unit.
KDP	1	Storage for the identification data field for the current subunit.
FMT	28	Storage array for the read-in input record format specification.
IVAR	1	The number of data fields in each input record.
NREAD	1	The total number of records to read from the input file.
NCOUT	1	The current number of records read from the input file.
MODE	1	The mode in which the input file is written: 1 equals binary; 2 equals BCD.

Array	*Dimension*	*Description*
NPLOT	1	The number of sampling units processed in the current data set.
KPOINT	1	The number of subunits read for the current sampling unit.
NCARD	1	The number of records read for the current-sampling unit.
NPSTEP	1	The total number of output tables defined in the control deck.
TNAME	LDETB	Storage array for the names (alphameric) of the output tables in the order that they are defined in the control deck.
ISTEP	1	The index number of the output table currently being processed.
INDEX	2	Temporary storage for final table indexes.

VII-E. OUTPUT TABLE FORMATS

Two alternative output table formats are available. The option is exercised in columns 12-16 of the output option card (item 302).

In normal job processing, these columns are left blank (not punched) and the table output is written on magnetic tape in binary mode. This form of output provides for rapid transmission of the output tables to the OUTPUT program in which they may be weighted, summed, labeled and printed, according to the sampling and table-selection options available in that program.

If columns 12-16 of the output option card (item 302) are punched with the word DEBUG, the table output will be printed in BCD mode (E specification). As the control word implies, this alternative will normally be used only in debugging program changes or control decks. It does not provide for any further processing of the output data.

The general order of the table output is the same for both alternatives. All table output from the job is in a single file. For the binary tape output, this means that there is only one end-of-file mark in the output and it appears after the last record output from the job.

Within the file, the sets of output tables for each input data set are in the same order as the data sets appear in the input file. Within the data set, the output tables are in the same order as are the corresponding output table definition cards (item 321) in the control deck. The output for a given table varies with the output option given in column 9 of the output option card (item 302). If the option is:

1. Only the table sums are given for each output table.
2. Only the table of means is given for each output table.
3. The table of means, followed immediately by the table of the variances of the means, is given for each output table.
4. The table of means, followed immediately by the table of the variances of the means, in turn followed immediately by the table of covariances of means, is given for each output table.

In the binary tape output, three types of record are used. The first type is repeated as the first record of each data-set output. The pair of records of the second and third types are repeated for every output table within the data set. The three types of record are described below.

Record number	*Word number*	*Description*
1	1	A number equal to one plus the number of identification words that follow in this record. This number is one greater than the number of data set identification fields specified in columns 13-27 of the input record identification fields card (item 334).
	2	The value of the data-set identification field specified in columns 13-15 of the input record identification fields card (item 334).
	3-6	Values of the remaining data-set identication fields specified in columns 16-27 of the input record identification fields card (item 334).
	7	The total number of output tables for the data set which follow this record. This number is equal to the number of output table definition cards (item 321) in the control deck.
	8	The total number of sampling units in the data set.

Record number	*Word number*	*Description*
2	1	An output table name, as given in columns 14-19 of an output table definition card (item 321).
	2	The number of rows, including column totals, in the output table named in word 1 of this record. This number is one greater than the number punched in columns 24-25 of the output table definition card (item 321) for this output table.
	3	The number of columns, including row totals, in the output table named in word 1 of this record. This number is one greater than the number punched in columns 27-28 of the output table definition card (item 321) for this output table.
3	1	The value in the first element or cell of the first column of the output table named in the preceding record 2, word 1. If the output option specified in column 9 of the output option card (item 302) is 1, the value will be a sum over the sampling units of the data set. Otherwise, it will be a mean over the sampling units.
	2-r	The values in the remaining cells of the first column of the table, where r is the number of rows given in the preceding record 2, word 2.
	(r+1)—(rxc)	The values in the cells of the remaining columns of the output table, where r and c are the numbers of rows and columns given in the preceding record 2, words 2 and 3, respectively.
	((rxc)+1)—2(rxc)	The values of the variances of the cells of the output table named in the preceding record 2, word 1. These words appear in the record only if output option 3 or 4 is punched in column 9 of the output option card (item 302). Otherwise the record ends with word (rxc).
	(2(rxc)+1)—3(rxc)	The values of the covariances between the cells and the total of the output table named in the preceding record 2,

Record number	*Word number*	*Description*
		word 1. These words appear in the record only if output option 4 is punched in column 9 of the output option card (item 302). Otherwise, the record ends with word (rxc) (output options 1 and 2) or with word 2 (rxc) (output option 3).

In the printed BCD output the numbers are in floating-point format (E specification). Essentially the same arrangement is followed as with the binary output, except that the output is broken into lines. There are eight entries (or cells) per line in columnar sequence, and as many lines are printed as necessary to record all the table entries.

For example, a table that has been defined as having 10 rows and 15 columns will appear printed in the following way: line 1 will represent column 1, rows 1-8; line 2 will represent column 1, rows 9-11 and column 2, rows 1-5. Row 11 of column 1 is the total of column 1 that has been provided by the program. The next line represents column 2, rows 6-11, and column 3, rows 1-2, and so forth through the entire table. If the option provides for tables of variances, these follow the last element of the means; and if the option provides for tables of covariances, these follow the last element of the table of variances.

The table is identified by a printed line that gives the table name, the entire number of rows and columns, and the entire number of cells represented in the printed tables. This number is merely the number or rows plus one times the number of columns plus one times the number of tables represented. If only means are printed, the number is one; if means and variances are united the number is two; if means, variances and covariances the number is three.

VII-F. SUMMARY OF ESTIMATING PROCEDURES

In this chapter the four output options available in program TABLE are presented in detail.

Vector notation is used to make the presentation of computing procedures compact and easy to read. An input vector, $\overset{I}{Y}$, is a one-dimensional array representing a sampling unit attribute. An output vector, $\overset{O}{Y}$, represents an output table (in general, a two-dimensional array or matrix) summarizing the sampling-unit attribute. A final output vector, $\overset{F}{Y}$, represents an estimate of the population attribute that corresponds to the sampling-unit attribute. Elements of these vectors are represented by $\overset{I}{y}_i$, $\overset{O}{y}_i$, $\overset{F}{y}_i$,

It must not be inferred from what follows that the arithmetic is the arithmetic of vectors or matrices although, in general, it is correct vector arithmetic as shown. What is implied is simply the sequential and independent application of the indicated operation to each pair of equivalent elements from the two vectors. In this sense, the procedures will generalize to the case of matrices; otherwise they will not.

Other notational conventions adopted here are the use of a bar over an attribute symbol (Y) to symbolize the arithmetic mean of an attribute, and the use of a dot that replaces a subscript $(y_{.jk})$ to indicate the sum over-all members of the set represented by the subscript.

OPTION 1.—Transform and Sum Sampling-Unit Attributes Over Sets of Sampling Units

Compute: $\overset{O}{Y}_j$

Given: A set $(j = 1)$ of $\overset{I}{Y}_{jk}$, and T

Where:

j = Subscript for the jth sample stratum or set of sampling units.

k = Subscript for the kth sampling unit

$\overset{O}{Y}_{j.}$ = An output vector (output table) containing the sum of the sampling-unit output vectors, $\overset{O}{Y}_{jk}$, which represent a summary of the sampling-unit attribute input vectors, $\overset{I}{Y}_{jk}$

$\overset{I}{Y}_{jk}$ = An input vector containing a sampling-unit attribute (a data field from the input-data matrix for a sampling unit)

T = A set of rules whereby the elements of the input data vector, $\overset{I}{Y}_{jk}$, are redistributed (transformed) to form the output vector (table), $\overset{O}{Y}_{jk}$

Procedure: $\overset{O}{Y}_{jk} = T\overset{I}{Y}_{jk}$

Output: $\overset{O}{Y}_{j.} = \sum_{k=1}^{P_j} \overset{O}{Y}_{jk}$

OPTION 2.—Transform and Compute Means of Sampling-Unit Attributes Over Sets of Sampling Units

Compute: $\overset{O}{\bar{Y}}_{j.}$

Given: Sets of $\overset{I}{Y}_{jk}$, P_j, and T

Where:

j = Subscript for the jth sample stratum set of sampling units

k = Subscript for the kth sampling unit

$\overset{O}{\bar{Y}}_{j.}$ = An output vector (output table) containing the arithmetic mean of the sampling-unit output vectors, $\overset{O}{Y}_{jk}$, which represent a summary of the sampling-unit attribute input vectors, $\overset{I}{Y}_{jk}$

$\overset{I}{Y}_{jk}$ = An input vector containing a sampling-unit attribute (a data field from the input-data matrix for a sampling unit)

P_j = The number of input sampling units in the stratum or set

T = A set of rules whereby the elements of the input-data vector, $\overset{I}{Y}_{jk}$, are redistributed (transformed) to form the output vector (table), $\overset{O}{Y}_{jk}$

Procedure: $\overset{O}{Y}_{jk} = T\overset{I}{Y}_{jk}$

Output: $\overset{O}{\bar{Y}}_{j.} = \dfrac{\sum_{k=1}^{P_j} \overset{O}{Y}_{jk}}{P_j}$

OPTION 3.—Transform and Compute Means and Variances of Sampling-Unit Attributes Over Sets of Sampling Units

Compute: $\overset{O}{\bar{Y}}_{j.}$, $V\overset{O}{\bar{Y}}_{j.}$

Given: Sets of $\overset{I}{Y}_{jk}$, P_j, and T

Where:

j = Subscript for the jth sample stratum or set of sampling units.

k = Subscript for the kth sampling unit

$\overset{O}{\overline{Y}}_{j.}$ = An output vector (output table) containing the arithmetic mean of the sampling-unit output vectors, $\overset{O}{Y}_{jk}$, which represent a summary of the sampling-unit attribute input vectors, $\overset{I}{Y}_{jk}$.

$V\overset{O}{\overline{Y}}_{j.}$ = The variance of $\overset{O}{Y}_{j.}$

$\overset{I}{Y}_{jk}$ = An input vector containing a sampling-unit attribute (a data field from the input-data matrix for a sampling unit)

P_j = The number of input-sampling units in the stratum or set

T = A set of rules whereby the elements of the input-data vector, $\overset{I}{Y}_{jk}$, are redistributed (transformed) to form the output vector (table), $\overset{O}{Y}_{jk}$

Procedure: $\overset{O}{Y}_{jk} = T\overset{I}{Y}_{jk}$

Output: $$\overset{O}{\overline{Y}}_{j.} = \frac{\sum_{k=1}^{P_j} \overset{O}{Y}_{jk}}{P_j}$$

$$V\overset{O}{\overline{Y}}_{j.} = \frac{\sum_{k=1}^{P_j} (\overset{O}{Y}_{jk} - \overset{O}{\overline{Y}}_{j.})^2}{P_j\ (P_j - 1)}$$

OPTION 4.—OPTION 3 Modified to Include Computation of Covariances for Ratio Estimates

Compute: $\overset{O}{\overline{Y}}_{j.}$, $V\overset{O}{\overline{Y}}_{j.}$, $C\overset{O}{\overline{V}}_{j.}$

Given: Sets of $\overset{I}{Y}_{jk}$, P_j and T

Where:

j = Subscript for the jth sample stratum or set of sampling units

k = Subscript for the kth sampling unit

$\overset{O}{\overline{Y}}_{j.}$ = An output vector (output table) containing the arithmetic mean of the sampling-unit output vectors, $\overset{O}{Y}_{jk}$, which represent a summary of the sampling-unit attribute input vector $\overset{I}{Y}_{jk}$

$V\overset{O}{\overline{Y}}_{j.}$ = The variance of $\overset{O}{\overline{Y}}_{j.}$

$\overset{O}{\overline{CV}}_{j\cdot}$ = The mean covariance of output vectors for sampling units, $\overset{O}{Y}_{jk}$, and the sums (totals) of elements in these vectors, $\overset{O}{Y}_{\cdot jk}$

$\overset{I}{Y}_{jk}$ = An input vector containing a sampling-unit attribute (a data field from the input-data matrix for a sampling unit)

P_j = The number of input-sampling units in the stratum or set

T = A set of rules whereby the elements of the input-data vector, $\overset{I}{Y}_{jk}$, are redistributed (transformed) to form the output vector (table), $\overset{O}{Y}_{jk}$

Procedure: $\overset{O}{Y}_{jk} = T\overset{I}{Y}_{jk}$

Output: $$\overset{O}{\overline{Y}}_{j\cdot} = \frac{\sum\limits_{k=1}^{P_j} \overset{O}{Y}_{jk}}{P_j}$$

$$\overset{O}{\overline{VY}}_{j\cdot} = \frac{\sum\limits_{k=1}^{P_j} (\overset{O}{Y}_{jk} - \overset{O}{\overline{Y}}_{j\cdot})^2}{P_j\ (P_j - 1)}$$

$$\overset{O}{\overline{CV}}_{j\cdot} = \frac{\sum\limits_{k=1}^{P_j} (\overset{O}{Y}_{jk} - \overset{O}{\overline{Y}}_{j\cdot})\ (\overset{O}{y}_{\cdot jk} - \overset{O}{\overline{y}}_{\cdot j\cdot})}{P_j\ (P_j - 1)}$$

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